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THE JANUARY SCIENTIFIC MONTHLY

Edited by

J. McKEEN CATTELL, F. R. MOULTON AND WARE CATTELL

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NEW BOOKS OF SCIENTIFIC INTEREST

Mathematical Snapshots. H. STEINHAUS. Illustrated. 135 pp. $2.50. G. E. Stechert and Co.

The purpose of this book is to draw attention to some objects which may have escaped notice and others which have been noticed without the observer surmising that they had anything to do with mathematics. The illustrations are accompanied by brief explanations. The book aims to appeal to the scientist in the child and the child in the scientist.

Structural Petrology. ELEANORA B. KNOPF and EARL INGERSON. Illustrated. xiii + 270 pp. Geological Society of America.

The writers attempt to explain the new method of investigation called "Gefugekunde" (structural petrology), its fundamental principles, which "have now formed the basis of the whole modern science of metallography," and leave the reader to evaluate the applicability of this method of study to particular geologic problems.

Air Conditioning. CHARLES A. FULLER. Illustrated. ix + 577 pp. $4.00. Norman W. Henley Publishing Co.

An effort has been made by the author to present in simple terms the various branches of air conditioning in their sequence, from the beginning of an air-conditioning problem to its solution.

Man and His Lifebelts. ERIC T. BELL. viii + 340 pp. $3.00. Williams and Wilkins.

Dr. Bell, who introduces his book with the statement that scientists are as stupid "socially" as any other mass of humanity, pricks all man's lifebelts through the ages—religion, democracy, industrial revolution, Marxism, economics, education, psychology and science.

Background to Modern Science. Edited by JOSEPH NEEDHAM and WALTER PAGEL. xii + 243 pp. $2.00. Macmillan.

A study of the importance of the history of science and technology in relation to the social and economic background of the time. Each section of the book is the work of an expert in the subject with which it deals.

The Human Machine. JOHN YERBURY DENT. vii + 299 pp. $2.50. Knopf.

In demanding that superstition be excluded in the treatment of the human mechanism, the author attempts an objective description of human behavior in an attempt to develop a sound materialistic and psychological attitude toward life.

The Peopling of Virginia. R. BENNETT BEAN. Illustrated. viii + 302 pp. $3.00. Chapman and Grimes, Inc.

A factual study of the waves of immigration to Virginia from 1607 to the present; short histories of the population of each county; detailed measurements of stature, sitting height, leg length and cephalic indices of present derivatives of Old Virginians.

Plants for the Connoisseur. THOMAS HAY. Illustrated. xi + 180 pp. $3.00. G. P. Putnam's Son.

This book covers a wide range of both old and new herbaceous plants of interest to the garden lover or plant collector. The majority of plants studied are illustrated by photographs.

Floralia. JUNE RAINSFORD BUTLER. Illustrated. xiii + 187 pp. $5.00. Van Ress Press.

"Garden Paths and By-Paths of the Eighteenth Century." The author expresses the wish that this book, which gives an account of horticultural endeavors of long ago, will aid gardeners "worthily to reflect their finer spirits through garden activities."

Cotton. HARRY BATES BROWN. 2nd Edition. Illustrated. xii + 592 pp. $5.00. McGraw-Hill.

A brief historical survey is followed by a discussion of the cotton plant in its various relationships—botanical species, physiology, etc. Next there is a consideration of cotton production and marketing, concluding with an account of products and uses.

Road Traffic and Its Control. H. ALKER TRIPP. Illustrated. xv + 414 pp. 26 shillings. Butler and Tanner.

The science of traffic and roads presented by the assistant commissioner of police of Scotland Yard, London. This study of traffic considers the immediate supervision of vehicles on the road, legislation, public opinion and psychology, road layout and equipment, town and district planning and many other matters.

World Natural History. E. G. BOULENGER. Illustrated. xx + 268 pp. $3.00. Charles Scribner's Sons.

The author attempts to set forth in a concise manner a résumé of the animal world as a possible incentive for more detailed study. He has reversed the usual scheme by beginning with the monkey and ending with protozoa.

Social Psychology. DANIEL KATZ and RICHARD L. SCHANCK. Illustrated. xiv + 700 pp. $3.75. John Wiley and Sons, Inc.

The plan of this book is to introduce materials and problems from the point of view of different participants in the social scene—the man on the street, the clinician and the social engineer.

Sportsmanlike Driving. Illustrated. viii + 106 pp. American Automobile Association. $1.00.

Designed to help those who wish to prepare or improve themselves for living in this motor age by profiting by the experience of others and learning the correct ways first. It is also intended to be helpful to those who desire to become leaders in improving traffic conditions.

THE SCIENTIFIC MONTHLY

JANUARY, 1939

THE GENESIS OF A CURRICULUM IN BIOLOGICAL ENGINEERING

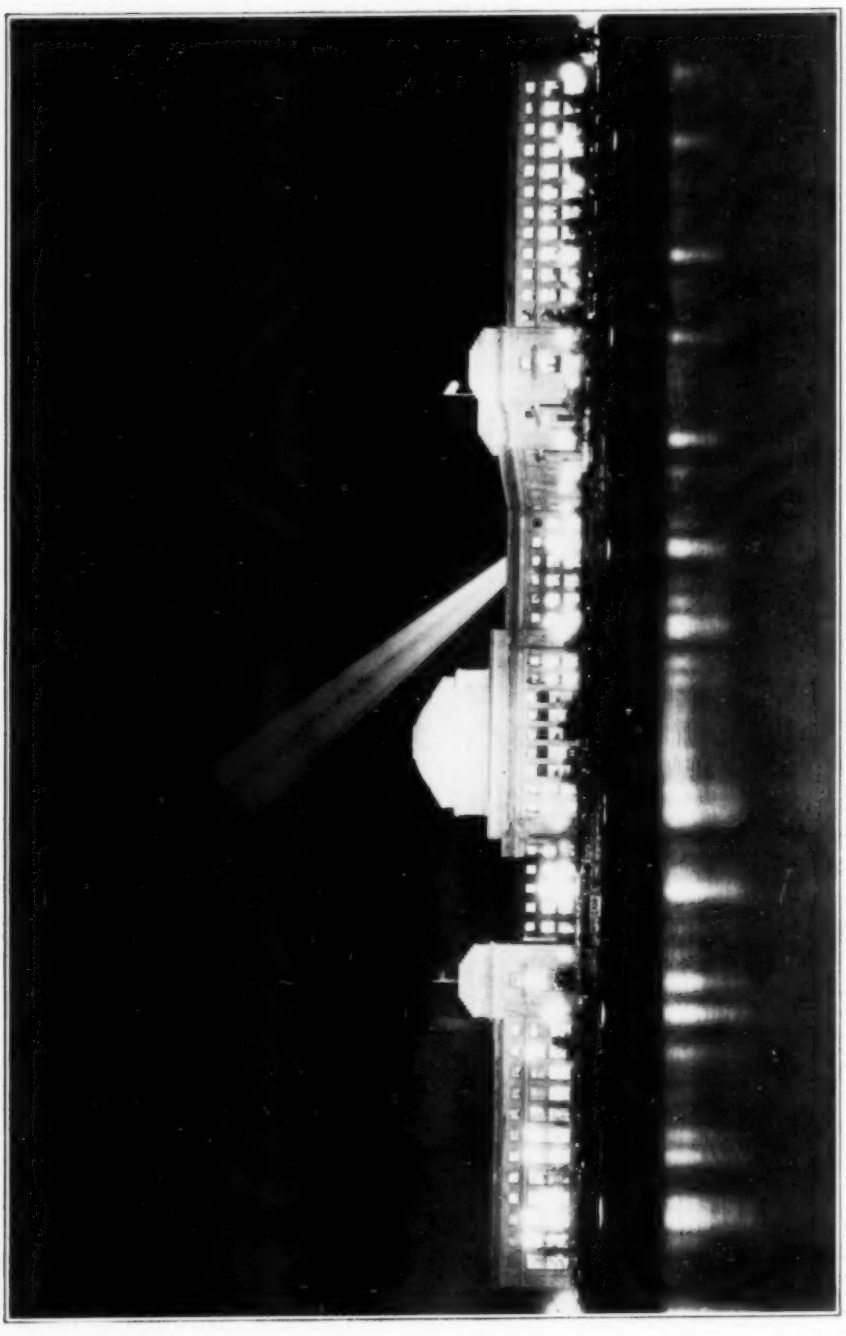
By President KARL T. COMPTON and Dr. JOHN W. M. BUNKER
THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

ONE hundred years ago there were but two types of engineers, "military" engineers concerned with the operations of warfare and "civil" engineers whose activities were directed toward problems of civil life. Each utilized many identical techniques in mensuration over the surface of the earth but with different objectives; each was concerned with the building of roads and bridges for which the same scientific data and similar mathematical computations were employed. Neither exercised a monopoly on any particular applications of science; their objectives were different.

For a time, all engineering in civil life was civil engineering, but as some of these engineers became engaged in delving into the earth to secure mineral resources, adaptations of usual procedures in the matter of structures, methods of tunneling, bracing and the like led to the designation of these specialists as "mining" engineers. On the other hand, those engineers who specialized in the harnessing of mechanisms to manufacture, employing the principles of mechanics, came to be known as "mechanical" engineers, the first college curriculum in this field being established at Rensselaer Polytechnic Institute in 1862. Shortly thereafter the increasing applications of electricity in its manifold possibilities to aid the mechanical engineer called for specialization of training and practice in that branch of physics comprised in the field of electricity, as a result of which technical courses in electrical engineering were developed at M.I.T. in 1882.

Meanwhile, the sciences of chemistry and physics and, to a less spectacular degree, the science of biology had been accelerated in their development, and their so-called boundaries expanded until they overlapped. The service of chemistry to biology was obvious, and biochemistry existed at the interphase between the two long before formal recognition of this state came with its definite designation by name.

Chemistry was impressed also into the service of industry, and the utilization of chemistry with a judicious employment of physical and mechanical engineering principles in chemical manufacture was explored systematically and with encouraging results. Alert to the possibilities with which this merger of chemistry and engineering was potent, in 1888 President Francis J. Walker at the Massachusetts Institute of Technology included in its curriculum the first program of training in chemical engineering. Fifteen years later Professor William Walker, teacher of industrial chemistry at M.I.T., conceived the pedagogical plan of instruction in unit processes, such as distillation, dehydration, heat transfer and other processes which are common to many industries, replacing the plan of detailed description of particular processes of manufacture. The art of train-



THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY AS SEEN FROM THE CHARLES RIVER AT NIGHT.

ing chemical engineers therefore emerged by metamorphosis, as it were, after an incubation period of fifteen years and, having spread its wings, took off in strong flight, which is still successfully maintained.

The applications of these basic principles in the engineering manner was the logical sequence to such preliminary pedagogical training. By the application of this view-point of unit processes to industry itself, order arose from chaos; the problems of chemical industry became reduced to common terms; technical advances in one branch of industry were transferable to other branches. In the short space of thirty years chemical engineering has become one of the most vigorous and useful of all the applied sciences.

Biology is the name given to one subdivision of natural science and relates particularly to life and the products of living things. Originally a matter of observation, description and classification, "natural history" designated the scope of biology. Following the period of description and classification of forms, there developed a period of inquiry into the nature of these forms, the changes which they were observed to undergo and the accumulation of data concerning the analysis of life processes. Thus there was developed a body of facts within the broad field of biology which came to be designated as physiology. Great advances in physiology followed the demonstration that the functions of life are largely manifestations of chemical reactions. Utilization by the physiologist of the expanding knowledge in the field of science designated as that of organic chemistry brought about a corresponding expansion in our knowledge of the phenomena of life, and the accumulation of chemical data related to physiological happenings constitutes the basis of the subscience physiological chemistry or biochemistry.

A noteworthy advance in the study of all branches of chemistry has arisen from the demonstration of the essential unity of its subject-matters with those of pure physics. Chemist and physicist alike investigate the structure of matter and its behavior, and chemical secrets are being resolved by experimental and theoretical physics.

Living and non-living matter have in common a structure of matter, molecules, atoms and electrons, subject to the same laws of energetics. The very term "physician" and "physicist" are derived from the same root, φύσις, meaning nature as distinguished from the spiritual, mental or moral world. In the early days of science there was no sharp distinction between animate and inanimate phenomena. Pioneers in scientific observation concerned themselves with medicine, physics and alchemy.

Like pendulums swinging in opposite directions, so the history of science shows often a tendency toward expansion by specialization followed by convergence. As knowledge of natural sciences grew, specialization was a necessary phase of development in its major fields. Medicine and engineering emerged as combinations of art and applied science, medicine being based upon biology and engineering upon physics. Both medicine and engineering have taken unto themselves that which they may require from the richness of chemical knowledge, and each has become more efficient by such a merger.

Convergence of specialized fields comes about when some fundamental discovery discloses the underlying unity, the basic processes, of two branches of science which have developed apparently divergently on less fundamental and apparently unrelated bases. A generation ago it was easy to distinguish between a chemist and a physicist; the latter dealt with matter in bulk, the former with changes in molecular constitution. There still exists what might be called a plumbing type of physics and the culinary type of chem-

istry, but in their interpretative and many of their operational aspects the two sciences are now completely merged, to their very great mutual advantage. Every competent chemist is to some degree a physical chemist, and no observer of physical interactions can escape observation of chemical changes. It was only lack of information which compelled men to proceed along different lines based on imperfect conceptions of what appeared in our ignorance to be different sets of fundamental laws.

We now have learned a little more of truth, and perceive that the physical laws which formulate the relations of matter and energy in the lifeless world also apply to these relations in the world of the living. Biological science is one category of facts, relations and laws concerning matter and energy, just as chemistry and physics are other categories of the same broad classification. No boundaries exist to delimit sharply the fields of natural science; each merges into the other as the grass on the suburban lawn merges with that of the neighbor's yard. Names which are attached to centers of interest in each field are for convenience in description and reference and do not represent individual factual entities.

It is well recognized that man's achievement, all through the ages, has depended to a large degree upon the tools at his disposal. Already the techniques of experimental physics and chemistry have been applied in the study of biology with success, and the greater precision of measurement and of description of biological phenomena made possible thereby have changed the character of modern biology from descriptive to analytical. It is especially true in biology, due to the unpredictable idiosyncrasies of living specimens brought about by individual variations of environment or of heredity, that only by repetition can tests of theory establish truth. True repetition can be effected only when reproducible precision of essential measurement characterizes the tests. Chemical and physical measurements in biological investigation have supplied the precision necessary for successful experimentation.

As a result of the era of specialization in all fields of science, the biologist trained in the past finds himself to-day incompletely informed of the finest techniques of his brother specialists in physics, chemistry and mathematics. To acquire a comprehensive background of biological information, he has not had time to specialize in other sciences; the magnitude of the variety of experimental procedures in the various fields is beyond the comprehension and attainment of one mortal, it would require a superman.

Cooperation of specialists would seem to supply one answer to the dilemma which each faces. Cooperation means working together, it requires the ability to give and take mutually, and this give and take must not generate into "You give and I take." Cooperation requires adjustment of ideas when ideas are based upon imperfect premises. Cooperators must be able to reason logically and to yield to logic. They must be able to argue without acrimony, to convince or be convinced. If the answers were known in advance, there would be no need for search or research. Since the answers are not known, they must be sought by the formulation of hypotheses and the experimental testing thereof. This requires information and reasoning together with experimental skills.

Where there is a little knowledge but not enough, two heads should be better than one in gaining more. But man is a stubborn animal; and scientists are prone to be opinionated. The line between confidence and conceit is vague; the one quality is necessary for achievement, but the other is irritating to one's fellow man. Hence there are problems of human behavior and human reaction to be met with in cooperation. Without patience, differences of opinion are rarely resolvable. The very imperfection of words to convey the meaning intended by the user requires meticulous definition in discus-

sion of scientific matters—and in other misunderstandings as well. To be specific, the biologist, chemist and physicist are conventionally trained in different terminologies and approach their problems with somewhat different attitudes. Cooperation does not come about like the amalgamation of mercury and other metal. It is something to be cultivated and nourished like a delicate organism until it acquires a sturdy habit of existence.

In 1931 one of us set about to study the technique of cooperation. Trained in biology, he formed a liaison with a fellow staff member of the research laboratories of organic chemistry, and later this was extended to calling in a physicist and various other experts. The results of some of these cooperative endeavors will be cited later in this chapter. The result of the first five years of this pleasant but at times turbulent experience proved several interesting things. One was that the art of cooperation can be learned and can be fostered. Another was the widespread interest held among scientists in matters which taxonomically belong in the field of another (perhaps analogous to the human interest we have in the business of other persons). A third was the demonstration that pooling of ideas and techniques is profitable in results.

Meanwhile, numerous sporadic inquiries from students in biology, physics and chemistry indicated some real interest in the question of preparation for professional work in biophysics or biochemistry. There is evidently an appreciation, by the thoughtful undergraduate, of the opportunities for useful work in the borderline fields between these sciences. The obvious answer to these inquiries seemed to be analogous to the reply of the modern dentist to the inquiry as to what one can do to insure teeth against decay, "See to it that your grandmother had a diet adequate in the basic nutritional elements, phosphorus, calcium and appropriate vitamins." The student who had specialized in physics without attention to biology had no means of acquiring a background of biological appreciation of natural phenomena without beginning all over again in biology; likewise, with the biologist who had spent his time on the various phases of his subject, exposing himself only to the conventionally required minimum of mathematics, chemistry and physics. As the result of experience and observation of the disadvantages of this procedure, and after consideration of the practical and pedagogical elements involved, we became convinced that the training of the biochemist or biophysicist could advantageously start simultaneously in biology and the sister sciences.

It is with satisfaction that one notes an agreement with this principle as indicated by the utterance of Dr. Detlev W. Bronk, director of the Eldridge Reeves Johnson Foundation, who, in addressing the Symposium on Biophysics sponsored in 1937 by the American Institute of Physics at Philadelphia, referred to the growth of biological research with the aid of the methods of physics and pointed out that too few students learn physics and biology together from the ground up.

Upon the above premises and with the objective of designing a curriculum in biophysics, two colleagues were called into conference, Professors Stockbarger and Warren. An analysis was made of the concepts, tools, techniques and opportunities involved in the proposed program, and it was agreed for a working premise that work in the proposed field will be largely concerned with experimental biology, and that the means of experimentation will include the application and the techniques of physical and chemical measurements of energy and reactions.

Among the types of energy likely to be usable there seemed to be the following: electromagnetic vibrations—infrared, visible, ultra-violet, radio frequencies, x-rays; radioactivity; electricity, electrons, neutrons, etc.; supersonics and

ultrasonics; heat; chemical energy; magnetism.

Among the ways in which these and other types of energy are likely to be involved are the following: stimulation of protoplasms; chemical changes induced in organic materials once living or the products of the once living; effects on enzyme action; therapeutic effects in disease; abiotic effects on deleterious cells or parasites; effects on hormones or vitamins; electrokinetics of membranes; permeability of surface films and membranes; electrophoresis of cells; mutations; photochemical reactions; spectroscopy of biologic materials; explanations of metabolism in general.

There may be required the construction and operation of devices for securing objective measurements of changes induced as above, and also the measurement and recording of the following: temperature, pressure, humidity, air motion, gaseous relations; motion and time; amplification of feeble energies without distortion, by mechanical or photronic electrical devices; radiation measurements, x-ray dosages, other radiations, such as radioactivity, cosmic ray counting, mitogenetic radiation; hydrogen ion concentration; oxidation-reduction potentials; vapor pressures; heat flow, insulation thermodynamics; surface tension; conductance and impedance in protoplasms; diffusion and osmotic effects across membranes; molecular weights and isoelectric points; colloidal phenomena; agglutination and antibody reactions; electrical potentials; Donnan equilibria; Helmholtz double layer phenomena; axone potentials and action currents; reflex time and tropisms.

Among the technical skills which will be useful in constructing experimental and recording apparatus the following are suggested: design and construction of amplifier circuits, transformers, meters; machine tool work, welding, hard and soft soldering; wood-working, glass-working, glass metal seals; vacuum pumps, maintenance and measurements of high vacuums, manometry, use of McLeod gauge and other devices for measuring gas and/or vapor pressures; production and maintenance of uniform or varying temperatures, including cryoscopic work; thermionic, vacuum tube, thyratron circuits; scientific photography and photometry; optical measurements; radiation measurements; spectroscopy, absorption and emission spectra, extinction coefficients; spectroscopic analysis of biological materials; supersonic devices; radiation sources (electromagnetic, monochromatic, etc.); optical filters; use of the research microscope, transmitted and oblique illumination; the ultra microscope, dark field, quartz lens microscope, lithium-fluoride microscope; monochromators, quartz, lithium-fluoride; gaseous conditions for same; preparation and handling of pure gases.

Among the fields of usefulness in which a biophysicist may find employment is research in pure or applied biology, as in: medical schools; hospitals; medical and biological institutes; universities; institutes of biophysics; food companies, packers, canners, bakers, shippers, etc.; manufacturers of pharmaceuticals, chemicals or drugs; industrial hygiene; governmental laboratories, agriculture, food, health and standards; unforeseen outlets.

Fortunately for our purpose, an examination of the various curricula in the eighteen courses of study already available in our institution disclosed a wealth of material dealing with the basic sciences. A mosaic of selected courses of instruction in biology, chemistry, electrical engineering, organic, physical and colloidal chemistry, mathematics, theoretical and experimental physics was fitted together without serious conflicts of time schedules which gave a first approximation to the desired new curriculum.

It was judged that an educational program in four years could not be suffi-

VII-A. Biophysics and Biological Engineering

First Year

First term			Second term		
Course No.	Subject	Units	Course No.	Subject	Units
5.01	Chemistry, General	7–4	5.02	Chemistry, General	7–4
8.01	Physics	6–5	8.02	Physics	6–5
D11	Engineering Drawing	6–0	D12	Descriptive Geometry	6–0
E11	English Composition	3–5	E12	English Composition	3–5
M11	Calculus	3–6	M12	Calculus	3–6
MS11	Military Science	3–0	MS12	Military Science	3–0
PT1	Physical Training	1–0	PT2	Physical Training	1–0

Second Year

5.11	Qual. Analysis	7–2	5.12	Quant. Analysis	7–2
7.01	Biology, Gen.	5–2	7.14	Comp. Anatomy	8–2
8.03	Physics	5–5	8.04	Physics	6–4
E21	Lit. & History	3–5	E22	Lit. & History	3–5
M21	Calculus	3–6	M22	Diff. Equations	3–6
MS21	Mil. Science	3–0	MS22	Mil. Science	3–0
	Gen. Study	2–2			30–19
		28–22			

Summer

5.41	Organic Chem. I	4–3
5.428	Organic Chem. Lab. I	10–0

Third Year

5.61	Phys. Chem. I	4–4	5.62	Phys. Chem. II	4–4
5.611	Phys. Chem. Lab. I	4–0	5.621	Phys. Chem. Lab. II	4–0
7.10T	Invert. Zool.	8–4	6.00	Elec. Eng. Prin.	4–4
7.301	Bacteriology	6–4	6.75	Elec. Eng. Lab.	2–2
Ec11	Political Economy	3–3	7.20	Physiology	6–4
	Language	3–5	Ec12	Political Econ.	3–3
		28–20		Language	3–5
					26–22

Fourth Year

6.01T	Elec. Eng. Prin.	5–7	7.84	Biophysics	6–3
6.761	Elec. Eng. Lab.	2–3	8.311	Atomic Struct.	3–5
7.80	Biochemistry	8–5	8.312	Atomic St. Lab.	3–2
8.09	Physical Meas.	3–2		General Study	2–2
8.161	Optics	3–6		Electives	20
8.162	Optical Meas.	3–2			49
		24–25			

Fifth Year

7.321	Adv. Bact.	3–4	7.82	Adv. Biochem.	6–3
7.81	Zymology	6–3	7.92	Biol. Eng. II	4–2
7.91	Biol. Eng. I	6–3	10.662	Colloid Chem.	2–4
10.661	Int. Colloid Chem.	2–4		Elective	9
	Elective	9		Thesis	20
	Thesis	10			50
		50			

ciently broad to give a fundamental grasp of the essential elements of biology, chemistry and physics here involved and at the same time go sufficiently into these fields to give power of using the concepts and techniques listed above. The proposed educational program must therefore be based upon a combination of undergraduate and graduate work. By extending the program through five years, the necessary minimum of training can be offered, including type applications of fundamentals to concrete biological problems.

This five-year program of study went into effect in September, 1936. Upon its satisfactory completion a student may be recommended for the degree of master of science in biological engineering and bachelor of science in biophysics (as of the preceding year).

The curriculum which is now in effect is presented herewith. The "unit" of class work or preparation consists of one hour per week for fifteen weeks; for instance, the symbols "7–4" mean seven hours of recitation, lecture or laboratory and the estimated preparation time of four hours per week.

The choice of the name "biological engineering" is the result of much thought and consultation, and it has been

adopted in spite of its temporary abandonment when we were first searching for the precisely appropriate title to describe our objective. The name biophysics is not sufficiently definitive, and biochemistry is insufficiently inclusive. Such varied etymological combinations as biurgy, biodynamics and biotechnology were examined and discarded. The designation accepted was urged by Dr. Vannevar Bush as being appropriate because our objective so aptly conforms to the well-known definition of engineering as "the art of organizing and directing men and of controlling forces and materials of nature for the benefit of the human race." Within this conception lies ample scope for every activity from instrumentation to theory, including biophysics and biochemistry (which, in fact, contribute greatly to the meaning of physiology) so long as the major objective is the marshalling of all available resources to aid biology for the benefit of humanity. With clear vision, Dr. Bush stated, "I know you don't like the name now, but it will grow on you as you think it over." He was right.

A few concrete illustrations of the results which have been derived from the pooling of scientific resources to a common objective will be cited.

Seven years ago Dr. Nicholas A. Milas, of the Research Laboratory of Organic Chemistry at M.I.T., being interested in the broad subject of oxidations, discovered and reported the production of a peroxide of secondary butyl alcohol prepared by irradiating this reagent with ultraviolet light. The scientific interest of this finding was in itself sufficient justification for the planning and effort expended in its demonstration. In the course of conversations with a colleague in the department of biology, speculation arose as to whether or not this new compound, containing a source of active oxygen, might not have the property of killing bacteria. A test with the appropriate methods for determining germicidal property substantiated the hope. Clearly this chemical novelty had potential value of useful application in an unforeseen direction. Another colleague, impressed with the favorable surface tension property of the butanol solution and irritated by the discomfort of a foot infection which had remained with him from his days in college athletics, expressed curiosity as to whether this reagent could possibly be effective in combatting epidermophytosis of the type commonly called "athlete's foot." Cautiously applying the butanol peroxide to one infected foot, leaving the other untreated as a control, no one was more surprised than he at the speedy relief from discomfort which followed and at the definite healing process which ensued. This observation naturally led to systematic testing of the fungicidal properties of the new reagent by approved cup-plate tests with serum agar, and its fungicidal value as well as its penetrating properties was found to be superior to the usual medicinal agents available for therapeutic use in this ailment.

The stability of the peroxide solution under ordinary storage conditions being inadequate for practical medical use, a further series of investigations by Dr. Milas resulted in a method of chemical synthesis of an allied but different compound, namely, the hydroperoxide of tertiary butanol which, having been put through the same paces with encouraging results, has been tried clinically in hundreds of cases with such success that the material has been put into manufacture and is now available to the medical profession. As a further instance of how unpredictable results may come from the testing of hypotheses, it is pertinent to state that this medicinal preparation, already proved useful for fungus infections of the skin, has found new and promising uses in oral hygiene and in dental surgery.

A second instance of the profitable combination of science and engineering is the development of an instrument, the electrocardiotachometer, whose applica-

tion has been in an unexpected direction. Based upon representations from European laboratories that in certain vitaminic deficiencies in the albino rat, the pulse rate of the animal is a useful diagnostic symptom, Professor R. S. Harris decided to investigate the pulse rate of some of his own white rats in the department of biology. There are at least two reasons why such a procedure is difficult. First, the albino rat, tame though it be, does not take kindly to having its wrist held; second, if by palpitation one endeavors to count the heart rate of the albino rat he finds himself in difficulty because that rate is normally between 450 and 500 beats per minute, which is too fast to count.

The dilemma was laid before Professor J. W. Horton, at that time attached to the electrical engineering department, and he called upon his recent experience in utilizing vacuum tube circuits for the purpose of counting cosmic ray impacts. By certain modifications, he devised equipment for picking up the minute voltages incident to each heart-beat through electrodes applied externally to the body of the rat, filtering out the bothersome muscle voltages, amplifying those desired, and fitting the impulses to an appropriate meter which, when calibrated, records instantaneously the desired rate of heart-beat. By the time that the kinks had been ironed out of this instrument its preliminary use had shown so great a variation in the pulse rate of a single animal during its waking and sleeping periods that the significance of the pulse rate as a diagnostic symptom was shown to be without value for the purpose intended. However, the application of this identical electrocardiotachometer to a patient under anesthesia during a surgical operation in a local hospital enabled the operating surgeon as well as the anesthetist to read the pulse rate of the patient at a glance and released one hand of the anesthetist, previously required for taking the pulse, for other useful purposes, and this application to human surgery has aroused much favorable and enthusiastic interest.

A third example of a contribution of physics to medicine arose independently of the development of cooperative effort in biophysics or biological engineering, but is a dramatic illustration of how science can be brought to the service of humanity. We refer to the work of Dr. Robley D. Evans, of our department of physics, who became interested in the unhappy condition which befell certain young women a few years ago while engaged in painting luminous dials on watches with radium paint who, by the careless practice of moistening their paint brushes on their lips to make a fine point, inoculated themselves unwittingly with radio-active material which is, of course, one of the most potent poisons known to man. In the hope of alleviating this condition of radium poisoning in the human being Dr. Evans secured the help of medical colleagues and with the active collaboration of Dr. Joseph C. Aub, of the Huntington Memorial Hospital in Boston, an expert on calcium metabolism, there was evolved the method of therapeutic treatment which has given the greatest relief to victims of radium poisoning. The medical part of this procedure involves the mobilization of calcium from bones into the blood stream and its elimination from the body. Radium, like calcium, when introduced anywhere into the body, migrates in part to the bones, where it is stored and where it may cause malignancy in the bones, resulting subsequently in death of the patient if even so small an amount as one millionth of a gram of radium is retained. But radium leaves the bones along with calcium when bone calcium is moved into blood and out of the body. Dr. Evans devised a most delicate Geiger counter and the ingenious method of using it to determine at any time with great precision not only the total amount of radium in the body, but also its anatomical position. This gave

the physician a tool for gauging the success of his treatment. When the patient has been depleted of calcium as far as seems safe, the treatment is then reversed and a diet rich in calcium is supplied and new calcium free from radium tends to reform a healthy bone structure. Dr. Evans was given the Theobald Smith award in 1937 for his part in this very valuable work.

A fourth illustration of a useful result from collaboration between departments is the development of a new method for the production of vitamin D from appropriate sterol precursors by application of the energy of particles of high velocity excited in the electromagnetic field of a high frequency radio oscillator. This method was conceived by a chemist who was acquainted with the electrodeless discharge. Drawn into the development were also a biologist interested in the vitaminic potency of the product, an electrical engineer as designer of the electrical equipment and several physicists acquainted with the properties of electrically excited particles. This process is being used in industrial production.

The problems of importance to the welfare of mankind which should be susceptible of solution by the biological engineer are numerous and of great economic significance. He will be a pioneer on a new frontier with vast possibilities for useful endeavor spread before his ken. An explorer in ill-mapped territory, he may indeed lose his way at times, but so did Christopher Columbus, who (as pointed out by Clarence Francis in an address before the Industrial Research Conference at Ohio State University on November 4, 1938), through an error in navigation did not find India, whose spices he sought. "It was a golden error! For what Columbus did was to come upon a new world, change the existing trade routes, awaken mankind's curiosity, spur explorations, stimulate scientific research, improve the world's food supplies and point the way to health and long life by way of the balanced diet." Columbus as a navigator may have been no more adept than many of his peers, but he surpassed them all in confidence and perseverance, and he was alert to capitalize an unexpected observation, qualities necessary for the successful prosecution of useful scientific research.

The yearly destruction of food and of food crops by animal and plant parasites runs into millions of dollars. More efficient fungicides and insecticides are required, and rational methods for their efficient use are needed. Campaigns for the eradication of such parasites as those which cause the Dutch elm tree disease and the chestnut blight must be organized and carried through for public welfare with the methodical planning of the engineer.

Termite destruction of wooden structures is a menace against which more efficient methods of combat must be devised with due regard to the breeding and nutritional habits of the invader.

In our harbors the damage by shipworms and other biologic infestations is of far greater magnitude than landsmen realize. Within the last two years in Boston Harbor alone the cost of replacing piling, wharves and bulkheads ruined by marine borers is of the order of five million dollars. New York harbor with its piers and docks has been free from significant trouble of this sort. Test boards maintained in the North River and examined monthly by Wm. F. Clapp, lecturer in marine economics at M.I.T., have shown the first shipworm, a 35 millimeter teredo, on November 29, 1938. This has followed the diversion of substantially 20 per cent. of the pollution from that body of water through the meritorious efforts of the Sanitary Commission, which proposes to divert an additional 30 per cent. in 1939. Shipworms in their invasive stage can not withstand sewage pollution; as it is removed, they may be expected to invade, and once they

are present one breeding season will result in their entry into unprotected wooden structures below salt water level. Once they have gained entry through minute holes which they bore, they tunnel as they grow until a porous shell of insufficient structural strength results and the piling fails to maintain its load. Means for combatting shipworms are known, but better, cheaper, more efficient methods must be devised and applied on a large scale to prevent tremendous economic loss from this menace.

Continued developments of physics and chemistry in the service of public health and of therapeutic medicine are to be expected, and these aspects of applied science must be not only developed but made applicable on a large scale for the good of all. Biology has already shown the way with aid of chemistry to combat malaria, diphtheria and many more of the communicable diseases; no one yet knows how to control infantile paralysis or the common cold. Pandemic diseases of the venereal group are still a scourge to mankind. We know relatively little of the transmission of virus diseases and not very much of the nature of viruses.

Recent biological byproducts of the new discoveries in atomic physics undoubtedly open up an enormous vista of opportunities for investigating the nature of biological processes in conditions of disease and health. A majority of the kinds of chemical atoms can now be produced in the radioactive state and used as "tracer elements" of prodigious sensitivity in the study of physiological processes. In some cases they can be used as therapeutic agents. Isotopes, also, can be used as biological or chemical tracers. Here are new tools, made available to the biologist by his colleagues in physics and chemistry, which may well rival the microscope and the x-ray in their ability to open up hitherto unexplored territory.

The human mechanism and the myriad forms of life which share its environment can be most intelligently controlled for the maintenance of health and the avoidance of ills only after man learns how these living mechanisms operate. The more complete his knowledge of the fundamental energy transformations and other chemical reactions of life in general and of human life in particular, the better can he expect to live and the more efficiently can he hope to promote the welfare of all.

Training in biological engineering is offered not as a mere intellectual invention but in recognition of an existing situation and a present need. The curriculum described above is designed to meet that need, and it was derived from a study of practical problems susceptible to cooperation between scientists each a master in his own field and sympathetically interested in the other's. Graduates with this new type of training should be equipped with technical skills and broad appreciation of fundamentals to a degree which, combined with moderation, zeal, persistence and ingenuity, should lead to success in research and in its applications.

A fresh field of useful endeavor lies before the young man of ability, imagination and courage. There are few if any ruts in this field into which the biological engineer may stumble. He must set his own course, for beaten paths are not there. No frontier of applied science has ever been presented to the scientific explorer more rich in possibilities of improving human welfare; no scientific explorer has been equipped with such diverse resources and instrumentation for useful research as are at the command of the biological engineer. Here is opportunity; how will it be met?

ALBERT ABRAHAM MICHELSON

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THE FIRST AMERICAN NOBEL LAUREATE

By Dr. ROBERT A. MILLIKAN

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It will probably be generally agreed that the three American physicists whose work has been most epoch-making and whose names are most certain to be frequently heard wherever and whenever in future years the story of physics is told are Benjamin Franklin, Josiah Willard Gibbs and Albert A. Michelson. And yet the three have almost no characteristics in common. Franklin lives as a physicist because, dilettante though he is sometimes called, mere qualitative interpreter though he actually was, yet it was he who with altogether amazing insight laid the real foundations on which the whole superstructure of electrical theory and interpretation has been erected. Gibbs lives because, profound scholar, matchless analyst that he was, he did for statistical mechanics and for thermodynamics what Laplace did for celestial mechanics and Maxwell did for electrodynamics, namely, made his field a well-nigh finished theoretical structure. Michelson, pure experimentalist, designer of instruments, refiner of techniques, lives because in the field of optics he drove the refinement of measurement to its limits and by so doing showed a skeptical world what far-reaching consequences can follow from that sort of a process and what new vistas of knowledge can be opened up by it. It was a lesson the world had to learn. The results of learning it are reflected to-day in the extraordinary recent discoveries in the field of electronics, of radioactivity, of vitamins, of hormones, of nuclear structure, etc. All these fields owe a large debt to Michelson, the pioneer in the art of measurement of extraordinarily minute quantities and effects.

I. Michelson, the Man

Of all those who take their place in the company of the immortals the world is intensely interested in knowing not merely their accomplishments, but how they got started in the line they followed and what manner of men they were. Not very much of this can be learned from Michelson's writings, much less than from those of most equally famous men, and for that reason this memoir must take on, to an unusual degree, the character of a personal narrative.

The total volume of Michelson's published work is very small. In an active life as a physicist, extending from the age of twenty-five to that of seventy-nine, he wrote two small books that are found in all libraries. The first is entitled "Light Waves and Their Uses" (University of Chicago Press, 1903). It represents his Lowell Lectures delivered in 1899. The second is "Studies in Optics" (University of Chicago Press, 1927), and consists of a condensed summary of his major researches. These books contain some revealing and quotable passages which are used by Hale[1] and Lemon[2] in interesting and informing articles on Michelson.

His bibliography of scientific papers contains but seventy-eight titles all told, and many of these are abstracts and most of them are quite short articles. Not a few of them are reprintings of the same article in different journals and different languages. One's knowledge of Michelson must be gained, then, more

[1] *Astronomical Society of the Pacific*, 43: 175, 1931.

[2] *The American Physics Teacher*, 4: 1, 1936.

from what he did than from what he said. Also, one must call upon the testimony of those who, like the present writer, lived and worked side by side with him for a quarter century and more. That testimony will, I think, be unanimous in the judgment that his most outstanding characteristic was his extraordinary honesty, his abhorrence alike of careless, inexact, ambiguous statement, as well as of all deception and misstatement. His was a remarkably clean-cut mind, which left little room for adjustment and compromise.

Every one knows that he was a remarkably accurate and dependable scientific observer, but not every one knows how well he succeeded in doing what every scientist should do but which many do not succeed in doing, namely, in carrying over that exceptional dependability into all his relations with his fellows. At one time, when he had become the subject of some criticism, one of the critics came to me and to another of Michelson's associates, and asked whether these criticisms were well founded. Our joint reply was, "Don't ask us; ask him. He'll tell you." The critic took the advice and returned with the statement, "He certainly told me!" His whole effort seemed to be to see and to state things just as they were. The writer played tennis with him for twenty-five years, and watched him call balls. In doing so he was always just and correct, but never generous either to himself or to his opponent. He did not even fool himself, as most of us do, in the analysis of his own motives. Even when those motives were incorrect from the standpoint of his associates, he stated them frankly and with amazing honesty, in one remarkable instance apologizing for his attitude and expressing regret that he was "built that way." Almost any one else would have rationalized his conduct into a virtue, and lied both to himself and his critics, as we are now seeing done so continuously and so deplorably in our political life.

I am quite certain that the last thing Professor Michelson would desire would be to have this memoir made merely a eulogy. I am therefore endeavoring to give first as correct a picture as I can of the man as I knew him through more than twenty-five years of intimate association.

If his most outstanding characteristic was his honesty, his second most notable characteristic was the singleness, simplicity and clarity of his objective—an objective from which he let nothing divert him, however great the pressure. He was an intense individualist, he knew what he wanted to do, he had confidence in his ability to do it, and he refused to let anything divert him from it, no matter what other interests had to be sacrificed or who stood in the way. The result was that he made no pretense of keeping widely informed outside his own field. Indeed, he was always depreciating his own knowledge even of the field of physics, despite the fact that he was quite fond of telling the incident of how he once told G. Stanley Hall that if he wanted to keep a first-rate physicist like himself at Clark University he would have to treat him like a first-rate physicist.

There is no doubt, too, that in fields other than physics his reactions were sometimes hasty and occasionally purely emotional. This was well illustrated at the time of the blowing up of the *Maine*. President Harper had asked the historian Van Holst and the ex-navy man and scientist Michelson to address the assembly of the students at the University of Chicago upon the situation that had been created by that incident. Van Holst counselled caution, delay and painstaking investigation before any action was taken or even thought of. Michelson was for declaring war at once and immediately taking drastic steps.

But the best illustration of his singleness of purpose is furnished by the early history of the Ryerson Laboratory.

From a scientific point of view this consisted very largely of the history of Michelson's individual contributions. Some of the personal sides of that history are worth telling here for the light they throw on Michelson, the man. I first met him at the exercises connected with the dedication of the laboratory at the spring convocation of the year 1894. He had been the commencement speaker, and in his address had emphasized the significance of refinement of measurement for the progress of science—a significance which subsequent years have shown to be vastly greater than even he foresaw, inspired prophet though he was. Incidentally, in that address he used another's words, I think Kelvin's, as to the unlikelihood of future discoveries coming from other work than that involving the sixth place of decimals. He afterwards upbraided himself unmercifully to me for ever having done so.

At the dinner which he gave in the evening of that day to some fifty visiting physicists he was rallied for introducing personal charm as an attribute of the coming six-decimal-place physicist, for with his jet black hair, his attractive hazel eyes, his faultless attire and his elegant and dignified bearing, he made a striking figure, though his height was not over five feet seven or eight. The next day I attended his first lecture to the group of some six or seven graduate students, who were there for the work of the summer quarter at the University of Chicago. He was himself the graduate department, giving the only graduate course. The impression that was made upon me by that course and by his presentation of the "visibility curves" which had recently been obtained—curves which enabled one by the aid of skilful observing and more skilful analysis to read for the first time the fine structure of spectral lines far beyond the power of any instrument to reveal it directly to the eye—was memorable. This course, along with about two conversations which I had with him when he came to my room to see how I was getting along with my measurements on the polarization of the light emitted by incandescent surfaces, impressed me with the fact that I was in the presence of one who had a far deeper understanding of optics than any one I had thus far met. Elegance of observational technique, elegance of analysis, elegance of presentation—these were, I think, the impressions made on all of us younger men who had a chance to see Michelson's experimental work and hear him present it. He always lectured twice a week and quizzed once on the ground covered in the two preceding lectures, and he could cover more ground in an hour than any lecturer I ever heard. The two texts which he relied upon mostly for the material of his lectures, when he was not presenting his own work, were Mascart and Joubert's "Electricity and Magnetism" and Rayleigh's "Sound." The material covered in his lectures embraced the whole fields of electricity, sound and optics. He did nothing with thermodynamics, to which he had a certain aversion, probably because of its extreme generality and lack of concreteness—I think he greatly underestimated its value and its accomplishment—and while he was sympathetic with the kinetic theory and molecular physics, he incorporated little of this field into his courses. Also, the newer physics—radioactivity, electronics and quantum theory—were largely outside the field of his interest, though of the Zeeman effect he made a careful study, both experimental and theoretical, and when x-rays were discovered he stepped aside from his routine, as nearly every one else did, to try to contribute something to the elucidation of the source and nature of the new phenomenon.

It was probably fortunate for me in my very limited relations with him as pupil

(summer of 1894, only) and my long-continued relations with him as a subordinate member of his staff, that I had my own problems in which he only assisted me incidentally, and that I was never either his immediate assistant or his collaborator; for at least in those earlier years Professor Michelson's attempts in Chicago at collaborative work, either with staff members or with graduate students, did not in general turn out very well either from his own point of view or from that of the collaborator. In the case of both of the two staff members with whom in the nineties he tried to do some work in common, difficulties arose, and when one of them left about 1900 he assured me that my "turn would come next." And yet during the next twenty-one years during which I was with him I could not have asked for more considerate and courteous treatment than I uniformly received from Professor Michelson. It is true that on two occasions I thought he was wrong and told him so, but his explanations were so completely straightforward and disarming that I could only laugh and tell him that he was the most honest man I had ever met.

His relations with graduate students during the ten years from 1894 to 1904 tell much the same story. He assigned but few thesis subjects and no small proportion of these turned out none too happily. I think it was in 1905 that he called me to his office and said, "If you can find some other way to handle it I don't want to bother any more with this thesis business. What these graduate students always do with my problems, if I turn them over to them, is either to spoil the problem for me because they haven't the capacity to handle it as I want it handled, and yet they make it impossible for me to discharge them and do the problem myself; or else, on the other hand, they get good results and at once begin to think the problem is theirs instead of mine, when in fact the knowing of what kind of a problem it is worth while to attack is in general more important than the mere carrying out of the necessary steps. So I prefer not to bother with graduate students' theses any longer. I will hire my own assistant by the month, a man who will not think I owe him anything further than to see that he gets his monthly check. You take care of the graduate students in any way you see fit and I'll be your debtor forever." From that time on Professor Michelson assigned very few, if any, thesis problems. And this decision was the correct one for him to make, for he gauged his own qualities and capacities correctly. He knew what he was best fitted to do, and he did not let anything or anybody deter him from that course. He took no part in general university administrative or instructional problems outside the department of physics. I never saw him in a faculty meeting despite the fact that, in the early days of the University of Chicago, faculty meetings were very important affairs where university policies were very thoroughly threshed out.

His regular departmental routine was as follows: He met his class of graduate students regularly three times a week for two lectures and one quiz. All graduate students took his courses when they were ready for them. His lectures were carefully prepared. They were very condensed, with most of the details left for the students to work out. They were considered hard courses. He worked every day with his personal assistant, and often with the mechanician, in his research laboratory, and about four o'clock he regularly went over to the Quadrangle Club to play tennis or billiards, at both of which he was quite proficient. His evenings he spent at home; for his life with his second wife, Edna Stanton (married in 1900), and their three daughters was an altogether happy one, although his earlier marriage had not in the end turned out successfully.

The foregoing characteristics explain,

perhaps, the fact that during his earlier years Michelson acquired the reputation of being somewhat unapproachable, difficult, dictatorial, even inconsiderate. If he possessed these qualities in the earlier part of his life he certainly lost them in the later part, for the mellowing effect of his later years was particularly noteworthy. It was commented upon by all his intimates, as well as by his students. It is shown, too, by the fact that his first wife, from whom he was divorced in 1897 and who was later Mrs. Margaret Hemingway Shepherd, and by whom he had three children, one daughter and two sons (one of whom is at present an ethnologist in the Bureau of American Ethnology of the Smithsonian Institution)[3] wrote me in 1932 that before his death he sent his lawyer to her to ask her forgiveness for any suffering he might have caused her.

II. Michelson's Parentage, Childhood, and Youth

Albert Abraham Michelson was born at Strelno, then in Germany, a small town near the frontier of Poland, on December 19, 1852. His mother, Rosalie Przlubska, was the daughter of a well-known physician, and was left motherless in early youth. In her various duties for the household she met, fell in love with and married the proprietor of a dry goods shop, a man of forty years, Samuel Michelson. She was then but eighteen years of age. Before 1855 two children had been born, a boy and a girl. Because of the troublous times existing in that year in Poland, they decided to come to America, where Samuel Michelson had a sister living in California. They took passage via Panama to San Francisco, and then moved on to the lovely little mountain town in Calaveras County called Murphy's Camp, described by Bret Harte in one of his stories, where Albert's early childhood was spent.

As the young Michelson grew older he was sent to San Francisco to school, where "he developed few companionships," but where he lived for several years with the family of the principal of the high school, who later paid him three dollars a month—his first earnings—to keep the physical instruments in order. When Albert was sixteen he went back to the home of his father, who by that time had moved his dry goods business to Virginia City, Nevada, famous because of the history of the Comstock lode and more famous because of the immortality which Mark Twain gave it. The elder Michelson wished his son Albert to enter the Navy, so when, the next year, there was a vacancy in Nevada's quota, Albert took the examination for congressional appointment to Annapolis. He tied with another boy, who through influence got the appointment while Michelson was made alternate, but also given, by the local Congressman, a personal letter to President Grant which it was hoped might enable him to get one of the ten special Presidential appointments at large to the academy. He obtained his interview with the President, who, however, informed him that he had already exhausted his ten appointments at large. Nevertheless, one of the President's naval aids told young Michelson to go over to Annapolis, since there was still a chance of a vacancy through the failure of one of the new appointees who had not yet passed his examination. After three days of waiting at Annapolis this hope failed, and Michelson was just starting back for Washington to try again with the President when the Commandant sent a messenger after him and informed him that the President had given him "an appointment at large." Since this was the eleventh such appointment Michelson always maintained that his career was started by an illegal act.

III. Michelson and the Velocity of Light

In November of that same year, 1877, while studying, for the purposes of a

[3] Very recently deceased.

lecture, the three purely terrestrial determinations of the velocity of light that had thus far been made—one by Fizeau in 1849, one by Cornu in 1872, both by Fizeau's toothed-wheel method, and one in 1862 by Foucault—a slight but, for accuracy, a very vital modification of the Foucault method suggested itself to Michelson, which, to quote his own words, "dispenses with Foucault's concave mirror and permits the use of any distance."

Foucault, and, following him, Newcomb, who with the aid of a relatively large congressional appropriation had for some time prior to any work by Michelson been working at a determination of the velocity of light by a modification of Foucault's method, had placed the rotating mirror between the lens and the mirror used to return the beam back to the rotating mirror. In order to get enough light this required the use of a relatively large rotating mirror, and in Foucault's case the distance between the two mirrors was only twenty meters. It is to be remembered, however, that Foucault's apparatus was designed to permit the insertion between the mirrors of a tube filled with water, for his primary purpose was to determine whether the speed of light was greater in air or in water, for this was the crucial problem of his day, and this problem he successfully solved. It is true, however, that with his arrangement it was impossible to get enough light to enable the use of a large distance between the two mirrors. Also, when in 1872 Cornu went at a precise, absolute determination he studied carefully and elaborately Foucault's rotating mirror method, and discarded it because he could not extend the intermirror distance to more than thirty meters. Michelson, though only an inexperienced youth of twenty-four, with that quick insight into the vital elements of an experimental problem which was characteristic of all his design work, saw what other scientists of the highest repute who had studied the rotating mirror method had failed to see, namely, that by simply placing the point (or line) source at the principal focus of the lens so that the beam went out from the lens as a parallel bundle of rays which could be returned on itself as a parallel beam by a plane mirror *placed at any desired distance,* and then using a *small,* rotating mirror placed just in front of the point source, he could use any distance that he wished without any loss of light. This would make Foucault's rotating mirror method altogether comparable with Fizeau's rotating toothed-wheel method for an absolute measurement. Between November, 1877, and March, 1878, he built at an expense of ten dollars a rotating mirror, and using with it a lens which he found in the physics lecture equipment at Annapolis he obtained a displacement of 5 millimeters, while Foucault had had a displacement of .8 millimeters. Michelson wrote these results to the editor of the *American Journal of Science.* This letter takes up half a page of the May issue of 1878, and is Michelson's first publication. At the suggestion of his wife, her father in July, 1878, gave him $2,000 for improving the precision of the method, and he was presently using a distance of 700 meters, instead of 20, and getting 133 millimeters deflection. As a result of all his early determinations by this technique he obtained the value 299,895 kilometers per second, a value which he regarded as correct to one part in 10,000.

This problem, with which his career began, was also the one with which it closed. Four years before his death, at the age of seventy-five, he published in the *Astrophysical Journal,* 65: 1–14, 1927, the final mean of the results of his measurement made by sending a beam from Mt. Wilson to Mt. San Antonio, California, and back, 35 kilometers distant. The method now used, however, is essentially a combination of Fizeau's method and of Foucault's, since now Fizeau's rotating toothed-wheel is re-

placed by a rotating octagonal mirror, and the time of double transit of the light is the time it takes one face of the octagon to rotate into the position of the adjacent face. The advantage of this rotating mirror arrangement is that the angle of the octagon can be measured much more accurately than the mean distance between the teeth of the rotating wheel. He got from these measurements the value 299,796 kilometers per second.

Not content with this experiment because of the possible disturbance of the air-path between the two mountains, he spent the last four years of his life preparing for and redetermining near Santa Ana, California, this velocity by means of multiple reflections between the ends of an underground pipe 1,600 meters long, 30 centimeters in diameter, from which the air had been pumped out to such an extent as to make it possible to measure directly for the first time the velocity essentially in vacuo. The final mean result, published after his death, may be taken as 299,774, which is one part in 2,500 less than the best mean of his earlier measurements, another illustration of the fact that even the best of us tend to overestimate the precision of our work. The introduction to this last paper was written by Michelson but ten days before he lost consciousness. As he wrote it, it had the same title as the paper with which he began his career, "On a Method of Measuring the Velocity of Light."

Going back, now, to the beginning of his career: By the measurement made in 1879 at Annapolis, Michelson had sprung at the age of twenty-six, and while he was still "Ensign Michelson of the U. S. Navy," into international repute as a physicist. That he received immediate popular acknowledgment is shown by the following interesting quotation from a local Virginia City paper published on May 15, 1879, less than a year after his first published determination of the velocity of light:

> Ensign A. A. Michelson, a son of S. Michelson, the dry goods merchant of this city, has aroused the attention of the scientific minds of the country by his remarkable discoveries in measuring the velocity of light. The *N. Y. Times* in an article says that "it would seem that the scientific world of America is destined to be adorned with a new and brilliant name." Ensign A. A. Michelson, a graduate of Annapolis, not yet 27 years old, is distinguishing himself by studies in the science of optics in measuring the velocity of light.

But the importance of Michelson's work on the velocity of light is not to be measured alone by the absolute determinations thus far considered. He began his work in the period in which physicists were trying to obtain crucial tests to distinguish definitely, if possible, between a wave theory and a corpuscular theory of light. Indeed, Foucault's method had been designed and used by him in 1862 primarily for the sake of finding by direct measurement whether the velocity in air was greater or less than the velocity in water, and he actually interposed a tube of water, closed at the ends by plane parallel glass plates, between his lens and his concave reflector and showed that the velocity is less in water than in air, as the wave theory demanded. In 1884, after Michelson had become (in 1883) professor of physics at Case School of Applied Science at Cleveland, he repeated this experiment of Foucault's and checked not only the latter's qualitative result, but he now made it definitely quantitative. He showed, also, that the ratio of the velocities in air and water is equal to the index of refraction, as demanded by the wave theory. He then performed the same experiment with carbon disulfide and here found the ratio of the velocities 1.75 instead of 1.64, as expected from the index of refraction. Confident, however, in the accuracy of his measurement, he published his results in spite of the apparent contradiction. Lord Rayleigh later removed the contradiction by showing that in a highly dispersive medium like carbon disulfide the

group velocity is less than that computed from the mean index of refraction, and that the theory was quantitatively in accord with Michelson's measurements. Michelson also tested directly the velocities of red and blue light and found the former 2 per cent. greater than the latter —a result of much importance at that time for the theory of dispersion.

IV. Michelson and the Interferometer

However important his work on the velocity of light may have been, the permanence of Michelson's place in physics undoubtedly rests in largest measure upon his invention of the Michelson interferometer and what he accomplished with it. Claude Bernard says that "a good technique sometimes renders more service to science than the elaboration of highly theoretical speculations," and George Hale has often remarked to me that "after all the progress of physics is written in the history of the development of new instrumental techniques." Be this as it may, the history of the interferometer shows how vitally theory and experiment cooperate in the progress of science.

Early in 1879 Michelson left the Naval Academy, where he had been instructor in physics and chemistry since December 15, 1875, and was then employed for a year at the office of the Nautical Almanac in Washington. He and his wife and their two young children then started for Europe, and he spent two years studying at Berlin, at Heidelberg and at the Collège de France. At Paris he acquired a good command of French and became well acquainted with the French physicists of that period, particularly Mascart and Cornu, the latter of whom had made by Fizeau's toothed-wheel method a very excellent determination of the velocity of light, the value of which then stood at 299,990, while Michelson's value was at that time 299,940. It is probable that it was his careful study here in Paris of Fizeau's work that got him started on his main lifework in interferometry. For it was as early as 1851 that Fizeau had made his remarkable experiment on the effect of moving water on the speed of light passing through it. The method consisted in bringing into interference two rays of light after their passage through parallel tubes in which water was driven with a high speed, in one tube in the direction of travel of the light and in the other tube against that direction. It was but a step from this Fizeau form of interferometer to the one used by Michelson in which the two components of the split beam of light are sent off in directions at right angles to each other and brought back by mirrors placed at right angles to each beam, to the original separating surface for the observation of the fringes. The complete control of the path of each beam, however, and the possibility of varying each path at will, or of introducing in either path materials of any sort whose optical properties it might be desired to study, gave it an extraordinary flexibility as a tool for making exceedingly refined measurements. It is not too much to say that Michelson spent a large part of his active life and did his most important work in devising new uses for this tool and carrying out researches of all sorts with its aid. In a sense, the tool had been here for decades before him, but why had not its possibilities been seen and utilized? Michelson once told me that when he first set up such a device in Paris and told Cornu how he got the fringes, Cornu was skeptical until he put a piece of cardboard in one of the right-angular paths and saw the fringes instantly disappear.

Michelson's first use of his interferometer was for testing the relative velocity of the earth and the ether. It was while he will still in Europe, at the age of twenty-eight, that he made his first try at this epoch-making experiment. He reports it in the *American Journal of*

Science, 22: 120 to 129, 1881. He had tried it first in Berlin, then moved to the Astrophysikalisches Observatorium at Potsdam. In his brief report he thanks Alexander Graham Bell for supplying the funds for the investigation, and is so confident of the correctness of the negative result obtained that he asserts that "The hypothesis of a stationary ether is thus shown to be incorrect."

It is not until 1886 and 1887 that this experiment, repeated at Case School of Applied Science with great care and refinement by Michelson and Morley, begins to take its place as the most famous and in many ways the most fundamentally significant experiment since the discovery of electromagnetic induction by Faraday in 1831. The special theory of relativity may be looked upon as essentially a generalization from it.

Only second to it in importance is the use which Michelson made of his interferometer, especially in the years 1887 to 1897, in proving, through his penetrating and very skilful study of the so-called visibility curves characteristic of different spectral lines, the great complexity of all save a very few of such lines. It was the analysis of these visibility curves which brought the discovery that the so-called red cadmium line of wave-length 6,438.472 angströms (an angström is a ten-millionth of a millimeter) is so extraordinarily monochromatic that it is desirable to express the length of the international standard meter in terms of it. At the invitation of the International Bureau of Weights and Measures, Professor Michelson, with his collaborator, Professor Morley, spent the year 1892 carrying through this very exacting undertaking, with the result that the number of the foregoing wave-lengths in this standard was determined as 1,555,165.5.

Under this head should also come the extraordinarily fine work on the application of interferometry to the measurement of the diameters of stars done at the request of Dr. George E. Hale and in collaboration with F. G. Pease at the Mount Wilson Observatory between 1920 and 1925, a measurement which, for the first time, made possible the direct determination of a stellar diameter, and, to take but one example, fixed the diameter of Betelgeuse at 240,000,000 miles—about a hundred times that of the sun. The essentials of the method had been published by Michelson as early as 1890.

V. Michelson, Spectroscopy and Geophysics

No event in Michelson's career showed the originality of his mind better than the echelon spectroscope, which appeared in 1898. Unlike the interferometer, the accomplishment of this instrument has not been large because of its very narrow spectroscopic range; but the idea of obtaining high resolution by using this particular means of getting into a spectrum of very high order was at the time so novel that spectroscopists the world over were surprised and delighted with it. It showed, too, how fundamental an understanding its author had of all the elements of correct spectroscopic design. Its appearance probably had much to do with stimulating the minds of Fabry and Perrot to attain high spectroscopic resolution by their modification of this route. This has found application to a somewhat larger number of problems.

The attainment of high spectroscopic resolution had by this time (1900) become a major objective with Michelson, and it was perhaps because he thought he had about exhausted the possibilities of the interferometer and the echelon for this purpose that he turned his attention to the problem that gave him more trouble and at the same time filled his associates with more admiration for him than any of its predecessors had done, namely, the problem of ruling very high resolution gratings. He had thought he could build a machine in a few months,

or at most a few years, which would give him the desired resolution, but he spent the rest of his life without reaching the point at which he was willing to drop the problem. He often said he regretted that he ever got "this bear by the tail," but he would not let go, and, in spite of endless discouragements, at the end of about eight years of struggle he had produced a good six-inch grating containing 110,000 lines (resolving power is measured by the number of lines times the order of the spectrum), which was 50 per cent. better than the best otherwise produced at that time, and in 1915 he produced both an 8-inch and a 10-inch, which are still "among the most powerful instruments of diffraction that the world possesses," although with the extraordinary developments of quantum and nuclear physics the problem has become so important for physics, astronomy, chemistry and even biology that a considerable number of institutions are now hard at the grating problem.

One of the finest things that Michelson ever said was inspired by his baffling experiences with his grating machines. It reads:

> One comes to regard the machine as having a personality—I had almost said a feminine personality—requiring humoring, coaxing, cajoling, even threatening. But finally one realizes that the personality is that of an alert and skilful player in an intricate but fascinating game, who will take immediate advantage of the mistakes of his opponent, who "springs" the most disconcerting surprises, who never leaves any result to chance, but who nevertheless plays fair, in strict accordance with the rules he knows, and makes no allowance if you do not. When *you* learn them, and play accordingly, the game progresses as it should.

The problem of the rigidity of the earth which Michelson, in collaboration with Gale, solved so magnificently in 1919 is unlike most of Michelson's work in that it was undertaken at the request of others, particularly the geologist, T. C. Chamberlin, who was intensely interested in knowing how rigid the earth as a whole is. If it acted throughout like a fluid, then the land would move just as does water under the influence of the moon and the sun, and there would be no water tides at all relative to the surface of the earth. Could not Michelson suggest and carry out a method of making an exact measurement? Michelson at once devised the following exceedingly simple and direct method which, however, save for the "fringe system" of measurement, had been suggested earlier, I think by Airy, though never actually tried. It consisted in burying about ten feet under ground two 6-inch iron pipes about 500 feet long, one running east and west, the other north and south, with an observation chamber at the junction point. The pipes were filled half full of water. The variation in the levels of the water at the ends of the pipes, as the moon and sun periodically produced their miniature tides in the water in these two pipes, were accurately measured by the movement they produced in a simple optical fringe system formed between the top of the water and a surface rigidly attached to the earth. The amplitude of the movement was from 6 to 11 microns. If the earth were not at all rigid, as already stated, there would be no relative movement of the earth and water in the pipes at all, and hence no movement of the fringes. If the earth were completely rigid the movement could be exactly computed from the pull of the moon and the sun. The movement was actually about half of that computed for an immobile earth.

These results, published in the *Astrophysical Journal* by Michelson and Gale for 1919, undoubtedly give the best values yet obtained of the earth's rigidity, as well as of its viscosity. The difficult tidal computations were carried out by F. R. Moulton, of the University of Chicago, and his staff.

VI. Michelson, the Artist

This sketch would not be complete without an endeavor to appraise some-

what more fully the artistic side of Michelson's personality. In a sense I have already paid the highest possible tribute to his artistry in describing the refinement and exactness of his measurements and the perfection of the design of his instruments, for are not discrimination in the choice of tools and methods and exact adaptation of means to end of the very essence of real art? Michelson was incessantly trying to perfect his artistic techniques, practicing his tennis strokes, taking lessons to improve his billiard shots. His students were continually commenting upon the perfection of the circles which in his lectures he drew with such ease on the blackboard. Is it at all strange, then, that he was interested in music and a good performer on the violin? The connection between his accurate analysis of spectral colors and his love of painting landscapes and seascapes is a little less obvious, but be that as it may, in Southern California, where he spent a considerable fraction of the last ten years of his life, he divided his time between scientific pursuits and painting expeditions to the beaches, arroyos and the High Sierras. In the summer of 1925, when I came down from a week spent studying cosmic rays in Muir Lake under the brow of Mt. Whitney, I found Michelson all alone seated with his easel in a favorable spot on the porch of the little Lone Pine Inn, painting the glorious view he had found there of the snow-capped Whitney. In other words, he not only had the skill of the artist but also the feelings of the artist. He wrote two papers in which he gave expression to these feelings; one written in 1906 is entitled "Form Analysis." In it he attempts a classification of symmetrical forms as they are found in nature, and expresses the delight he found in these discoveries. He made this analysis, however, rather as a recreation than as a serious study. The other paper, written in 1911, is on "The Metallic Coloring of Birds and Insects," and in it, while he has set himself the scientific objective of finding whether the iridescent colors found in birds and insects are due to pigmentation, interference or metallic reflection, he gives expression to the feelings aroused in him by these beautiful color effects found in nature. Also in a paragraph from the Lowell Lectures he uses the following words:

> The aesthetic side of the subject is by no means the least attractive to me. I hope the day is near when a Ruskin will be found equal to the description of the beauties of coloring, the exquisite gradations of light and shade, and the intricate wonders of symmetrical forms and combinations which are encountered everywhere.

In 1928, a few years before Professor Michelson's death, a conference on the Michelson-Morley experiment was held at Pasadena. It was a distinguished gathering, with both Lorentz and Michelson having a part in the program. The latter was scheduled to make a final report on the repetition he had just made on Mt. Wilson of this famous experiment. Roy Kennedy, a young physicist who had repeated this experiment at the Norman Bridge Laboratory in a new way and with much precision, preceded Michelson. With a generosity and courtesy altogether characteristic of him, Michelson rose and, complimenting Kennedy enthusiastically upon the beauty and precision of his experiment, said: "Your work, Dr. Kennedy, renders my own work quite superfluous. I should not have undertaken it had I known you were doing it so well." It was one of the finest tributes Michelson could have paid *to himself*—a wonderful ending of a wonderful career, for this was Michelson's last public appearance.

WHICH WAY SCIENCE?

By Dr. HARLAN TRUE STETSON
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SCIENCE finds itself in a strange dilemma. It has made life easier and added to man's happiness and at the same time, in the event of war, it clouds the future with unspeakable horrors. Science is so intricately woven into our social and economic existence that she is a goddess both worshipped and feared. Science has cut the cost of production until even hitherto luxuries have fallen into the "must" class of commodities for nearly all standards of living. The machine age which has followed in the wake of scientific discovery has created new industries and disrupted old ones, causing many social and industrial maladjustments.

There is no question that the world to-day is in the midst of a social, industrial and economic evolution of far-reaching consequences. No one can deny that science has had its part in creating and complicating the present world picture. The prestige which science holds in the minds of multitudes can not but impress those who labor in her laboratories with the power and the responsibility that is theirs in fostering the aims and methods of science for the welfare of mankind. What can science do towards the control and use of its products for the good and not the destruction of society?

While confronted with such a question, there is perhaps a note of encouragement in that recent events make clear that both the negative and the positive assets of science may work side by side to constructive ends. On the negative side, the very thought of the horrors of the wholesale destruction that science can connive in the event of war has undoubtedly been a strong deterrent from engaging in a conflict that might well bring about the very ruin of civilization itself.

On the positive side, we have had an exhibition in international affairs of the application of the spirit of science that teaches a rational rather than an emotional approach to any problem, substituting methods of trial and error for assault and battery. Furthermore, scientific inventions themselves played their part in bringing about a four-power pact that for the moment seems to have stayed a European conflict. In 1938 negotiations could be accomplished in an hour which two decades ago would have required delay that might have been disastrous. While the world waited breathless for the fate of Europe, transoceanic and international telephone lines brought diplomats into instant communication. Airplanes conveyed plenipotentiaries from nation to nation, while public opinion was being moulded by world-wide radio broadcasting that constantly informed the world of every development in the European crisis.

It is significant that with war clouds hanging over Europe representatives of the American Association for the Advancement of Science met with members of the British Association for the Advancement of Science last July to consider ways and means by which a closer affiliation between these large scientific bodies might be accomplished with the ultimate joint purpose of making science a more dominant factor in guiding the destiny of world affairs.

These associations represent as no other organization the united front of science in the United States and in the United Kingdom. It is perhaps a bit unfortunate that our own American Association has too long been considered by many scientists as an aggregation of technical associations, each quite sufficient unto itself. But the hope is stirring

that in its various attempts to arrange conferences on science and society the scientists who compose our association will become aware of their civic responsibilities, which are fast becoming apparent whether we wish or do not wish to have our researches interrupted by such distractions. Most creative minds are probably by nature largely introvert. This may account for the painful lack of any unified action on the part of scientific men to leave their cubicles for the arena. The present trend of world events suddenly awakens us, however, to the fact that unless those who have created the offspring of science unite to guide and educate the masses in the spirit of science to a larger degree than has at present been done, research men may be suddenly awakened to find their laboratories in ruins and the dreams to which they had devoted their lives lost in the smoke of the impending chaos of a world struggle.

Five years ago at its meeting in 1933, the American Association passed a resolution framed by Drs. Robert A. Millikan and Henry Norris Russell which read as follows:

> Our existing liberties have been won through ages of struggle and at enormous cost. If these are lost or seriously impaired there can be no hope of continued progress in science, or justice in government, or international or domestic peace, or even of lasting material well-being.
>
> We regard the suppression of independent thought and of its free expression as a major crime against civilization itself. Yet oppression of this sort has been inflicted upon investigators, scholars, teachers and professional men in many ways, whether by government action, administrative coercion or extra-legal violence.
>
> We feel it our duty to denounce all such actions as intolerable forms of tyrrany.
>
> There can be no compromise on this issue, for even the commonwealth of learning can not endure "half slave and half free." By our life and training as scientists and by our heritage as Americans we must stand for freedom.

While such a notable declaration of scientific freedom is seconded by every true scientific worker throughout the world, it is primarily a protest and denunciation of infringements of liberty, leaving a constructive program for remedial action still to come. In urging some concrete action, Watson Davis in writing in *Science News Letter* for October 2, 1938, says:

> If science is to rescue the society it has created, and if the world at large is to preserve in freedom and tolerance the intellectual urge that gives it continual rebirth, there must be some mechanism, whether organized or not, that makes this possible.
>
> Whether the new science movement takes the form of a new intellectual brotherhood, a new political party, or an infiltration into existing progressive movements, it must be articulate, self-assertive, and combative within the limits of the scientific method. It must become a crusade with truth as its only dogma.

The great "intellectual brotherhood" to which Mr. Davis refers does exist among scientific workers not only in this country but throughout the world. Nothing is more apparent when scientists meet in international congresses than the fact that political, racial and social differences are forgotten in the eagerness to discuss the aspects of a common scientific problem in which workers throughout the world may be engaged. Much undoubtedly can be done to further filial relationships among scientists. If, on the other hand, a world conflict starts up on the aggressive move of any totalitarian state, we can rest assured that it will not have been brought about by members of the brotherhood of science. But some factor more effective than that of filial interests alone must become apparent.

Mr. Davis's suggestion that a new political party with which scientists as a body might become affiliated would, I believe, be unfortunate and unworkable. Science which recognizes no political barriers, races nor creeds can not afford to ally itself directly with any political party as now exists or that appears likely to exist.

Mr. Davis's suggestion of "an infiltration into existing progressive move-

ments" appears to be a particularly happy phrase. No political party gains control or stays in power, and no dictator rules except ultimately in accordance with the will of the people. It must never be forgotten that public opinion is the last court of appeal. The unfortunate fact is perhaps that public opinion is more easily moulded by political speech-making than by the colder rational application of the scientific method of thinking. This is perhaps partly our own fault. Too long have too many scientific men held aloof from the world of affairs. Too long, perhaps, have we been concerned with guarding our standing among academic intellectuals while ignoring the people whose majority vote rules in a democracy and whose subservience is necessary to any dictatorship.

Fortunately, much has been done in recent years to "infiltrate" the doings of science into the reading of the general public. An increasing number of scientists are sharing with the rank and file the results of their labors, even at the risk that inadequate statements may be circulated by the press at the expense of a certain prestige among colleagues who fail to understand the need for popularization of science. There is indeed a need for far more popularization of science in still plainer language—not for the unintelligent but for the vast majority of intelligent people who make up the nation but to whom scientific terminology is as non-understandable as is the vocabulary of the medical profession to the architect or the engineer. Science, which depends for its existence upon public good will and, in the end, public financial support, can well afford to keep the world constantly informed of its achievements other than in technical language. Perhaps the day will come when every editor of a scientific journal shall request in addition to the technical manuscript a paraphrased summary in ordinary English recounting the significant results of each piece of research. This might incidentally help a scientific worker to evaluate the significance of his own contribution to the society in which he dwells.

The chief of each bureau is probably the one who best knows the needs and requirements for the maintenance and normal progress of scientific investigations in his field. Each bureau chief must present his requirements yearly to Congress through the director of the budget, a political appointment often excellently made, but without reference to scientific training or experience. The incumbent of this office must pass on the relative merits of the appropriation proposed with the result that all too often appropriations may be unnecessarily augmented or painfully curtailed, depending upon the ability or lack of ability of salesmanship on the part of the chiefs of bureaus. While certain of the bureaus have the advantage of advisory bodies comprised of highly trained scientists and engineers, why is there not a responsible officer of the government or a board selected from among scientific men whose training and experience would allow a satisfactory evaluation of the relative merits of all the scientific projects that the government controls? To such an officer or board, chiefs of bureaus might appeal with the assurance of an adequate hearing of their needs and proposals.

To be sure, in the history of the country three boards have already been created that presumably should act in an advisory capacity to the government in scientific matters—the National Academy of Sciences, the National Research Council and the Science Advisory Board.

The National Academy of Sciences was called into being by President Lincoln in 1863 at the time of national emergency. It was incorporated by Congress to report upon matters in science and art

whenever called upon. The academy has frequently been of service to the government in our national history.

In 1916, under the administration of President Wilson, the National Research Council was organized, largely through the efforts of the late Dr. George Ellery Hale, to act as an advisory body in scientific matters, again in a time of national emergency. Ostensibly its function still exists, though it is seldom called upon for advice by the government.

With the inauguration of the New Deal Administration under President Roosevelt, a new kind of national emergency existed, and a Science Advisory Board was called into being to implement the functions of the National Research Council and to advise the government relative to the administration of its scientific bureaus. The excellent report by its chairman, Dr. Karl T. Compton, was distributed in December, 1934. It was noteworthy that most of the recommendations made by this advisory board as to specific questions raised by the government were acted upon favorably. However, additional recommendations, initiated by this Science Advisory Board, though of far-reaching significance, were not acted upon. Is advice on scientific matters by the national administration needed only in times of emergency? When a body of scientific men has been created by the government for scientific advice, is it inappropriate that they proffer advice except on questions specifically framed by the administrators themselves? When a new administration comes into being in Washington, or a new emergency arises, will it again be necessary that another advisory body of scientists be created as though such establishments that have already come into being through executive order did not exist? What is wrong with our scientific organizations that such should be necessary?

When scientific problems arise of national and international concern and of sufficient importance to make government cooperation desirable, it is indeed most unfortunate if the National Academy of Sciences, the National Research Council or the Science Advisory Board can take no initiative under a democratic government in approaching our federal administrators in such matters. Is there not opportunity here for science to unite in action, and through the creation of an intelligent public opinion make possible the continuation of an effective advisory board for science which shall have direct access to the federal authorities with the same assurance of recognition accorded it on occasions when advice is sought?

Have scientists perhaps been at fault that the present situation exists? Administrations come and go, but the National Research Council, with much the same organization, has continued on under Presidents Harding, Coolidge, Hoover and Roosevelt. Through these political vicissitudes the preservation of the dignity of the National Research Council has never been challenged, but can this representative body of scientists in its peculiar relation to the Federal Government continue to expect that overburdened officials carried in and out of office through the ebb and flow of the political tides will recognize the importance of science in our society, or the existence of the National Research Council in its capacity to advise, if nothing whatever is done about advising them of its existence?

Why should not the guardians of the faith of science take the initiative with each change of administration and through suitable approaches see to it that the council is brought into as close a contact with the government administrators and representatives as is the case with leaders of labor and of industry? If the dignity of science forbids, then science might well exchange something of its dignity for a political recognition that would assure as much prestige in national affairs and as intelligent a welcome

to officialdom as is granted commercial, industrial and labor organizations throughout the United States.

The aggregate expenditures for scientific research, including federal, departmental, state and private educational institutions, and our industrial laboratories taken together represent so significant an enterprise in this nation that it should command the attention of every Senator, Representative and taxpayer in the country. Public opinion could bring this about if scientists as a body were aroused to action.

The question of some form of federal control of public health, socialized medicine and a plan for hospitalization insurance has already attracted wide publicity. It has agitated the whole medical world. If such progressive movements are to take place, what is to insure that such federal control shall be above political propaganda? This is but one instance where there is a growing consciousness of a new relation of government to matters of science. Any plans covering medical or other scientific activities should be worked out with due deliberation to insure an intelligent control, irrespective of party or political affiliation.

The education of public opinion is a long and tedious process. But the patient and persistent efforts of a united scientific body towards this end should be fruitful of results in due time. If a little more than two decades is needed to train for military purposes a new generation, then the same amount of time spent in an organized effort for education in scientific intelligence would work wonders. So often has the teaching of history, literature and allied subjects so glorified the results of military achievement that rising generations learn too easily to place undue emphasis on this phase of social progress. When scientific achievements and the men who have pushed back the barriers of knowledge have been given an equal emphasis, a far greater proportion of hero-worshippers among our youth will find their heroes in science.

One can not but wonder that the teaching of science in our schools and colleges may have been guided all too much by emphasis upon the technicalities of the subject rather than by the experience and methods of science as applied to clear thinking and to developing a true basis for a sense of values. When one finds a science requirement in the curriculum irritating to a pupil who makes use of radio, automobile, airplane and many other devices of science and engineering, one wonders where the fault lies. From such reports that come in from overseas one would think that the Union of Soviet Republics was far more progressive in the scientific education of youth than is the United States of America.

Through a new emphasis in educational curricula and a further and more extensive popularization of science among peace-loving nations, one might expect that economic and political differences would become more easily adjusted. Nations would unite in the conquest of the frontiers of knowledge. One is indeed a pessimist to think that the present accomplishments of science are other than the beginning of a national prosperity such as civilization has yet to see. Such new trends of emphasis together with a more direct impact of science upon governments could accomplish much in the next two decades. Many of the problems of science to-day can not be solved except through the cooperation of workers in various fields of science, and there are many scientific problems which must wait for solution upon international cooperation alone.

In September, 1939, there will meet in Washington a congress of scientists which will be the first of its kind to meet in this country by invitation of the President of the United States. The occasion will be the seventh assembly of the International Union of Geodesy and

Geophysics, a scientific body comprising thirty-five adhering nations devoted to increasing our knowledge of the earth. To quote Professor Longwell, of Yale:

> Probably no scientific association covers a broader field of interest than the Union of Geodesy and Geophysics. The Union is made up of seven constituent associations, devoted to geodesy, seismology, meteorology, terrestrial magnetism and electricity, physical oceanography, volcanology, and hydrology. Physicists, geologists, geographers, and many types of engineers, in addition to specialists representing some of the particular fields suggested in names of the associations, find a common meeting ground in the Union, which owes its origin and its continued growth to the interlocking problems crossing the borders of the several physical sciences in all of the countries. The meetings of the Union, held at three-year intervals, not only promote international cooperation in scientific enterprises but also help materially to foster international good will.

There is probably no field of scientific endeavor so dependent upon international cooperation as this field of the earth sciences. There are many international unions such as of astronomy, mathematics, applied mechanics and engineering, sugar cane technologists, etc. None of these is so dependent upon international cooperation as that of the sciences of the earth. It is desirable, for example, in particular problems of astronomy that we have the cooperation of observatories scattered around the world. Activities on the solar surface are lost to us while the sun is below the horizon, and the record of light changes of certain variable stars would be broken if observers on the other side of the earth did not clock their behavior while they are below our own horizon. International cooperation makes possible the establishment of observing stations in the southern hemisphere for gathering data on stars invisible in the northern hemisphere. But to a very great extent, we can observe stars in our own country that are observed twelve hours later on the other side of the world.

When it comes, however, to be a basic study of weather or continental and oceanic structure of the earth on which we live, we are at a complete loss for fundamental data in regard to this planet and its atmosphere, did we not have knowledge gleaned by scientific methods from those countries where important territories of this globe are entrusted to other governments than our own. It is significant that in spite of European turmoil, an invitation can be issued in the summer of 1938 by the President of the United States through the Department of State to send representatives of thirty-five nations for the consideration of fundamental problems in the earth sciences that recognize no trade barriers, no political differences or racial demarcations. With the emphasis of nations resting upon matters of such fundamental importance to our economic existence, science is fostering an international good will that we can confidently believe postponed in no insignificant way the day of strife.

The American Association for the Advancement of Science, organized in 1848, is the oldest truly representative national scientific society in the United States. To quote Dr. Moulton, permanent secretary of the association:

> It is the federation of the most important forces, at least in the long run, that are operating on the continent. It is demonstrating that the whole of science is greater than the sum of its parts. . . . The voice of the association is increasing. The combined voice of science in America. . . . The association has more than 18,000 members and the membership of its affiliated societies (including duplications) is approaching a million.

It may well be that the American Association for the Advancement of Science is the logical body already organized competent to act upon such of the measures as we have been discussing above. There is need for action. Which way will science go?

SCIENCE IN VIRGINIA

By WILLIAM H. WRANEK, JR.
UNIVERSITY OF VIRGINIA

VIRGINIA, host to the American Association for the Advancement of Science for the December, 1938, meeting, is more widely known for the achievements of her sons in the field of statecraft and politics than for her contributions toward the development of the natural sciences.

Early colonizers were absorbed in making a living in a wilderness. Few could spare time to study, to write notes and to draft reports on their new-found land. It was enough to produce necessities, and perhaps a cash crop of tobacco. Scientific investigation was not for them. Berkeley, one of the early royal governors, gave thanks that there were no free schools in the colony. When the sons and grandsons of the settlers had moved from the stockades of Jamestown to the brick and stone of Williamsburg and later of Richmond they were preoccupied with making a democracy, and their speculations had more to do with the relationships of man with man than with the nature of the world about them.

Of the Virginia founding fathers who strove to better man's position Thomas Jefferson was the one who gave most serious thought to the natural sciences. Jefferson was not content with freeing the mind and spirit of man; he wanted to give him a better world in which to live and to enjoy that freedom, to provide more comfortable dwellings and a more varied and prosperous agriculture and industry, to increase man's health and happiness.

When, in his latter years, Jefferson founded the University of Virginia he enumerated the advantages of the higher grade of education, one of which was to enlighten the citizens "with mathematical and physical sciences, which advance the arts, and administer to the health, the subsistence and the comforts of human life." The curriculum he proposed and saw established at his university in 1824 included all the natural sciences.

In 1797 Jefferson was elected president of the American Philosophical Society, which had been formed in Philadelphia years before, and when he took office he was one of eighteen Virginians who had become members of this society "for promoting useful knowledge."

One of the Virginia members of this young organization, James Rumsey, was making practical use of the power of steam, and on December 11, 1787, a steamboat constructed according to his plans carried passengers across the Potomac River, making a speed of four miles an hour against the current.

In the Shenandoah Valley, in two adjoining counties, the grain reaper was first devised by Robert McCormick and was perfected by his son, Cyrus McCormick, and a chain-stitch sewing machine was invented by James E. A. Gibbs. Chemical studies carried on by John William Draper, while he was a professor at Hampden-Sydney College, led to the taking of the first photograph ever to be made in America and of the first photograph of a human face ever to be taken.

The name of Matthew Fontaine Maury, "pathfinder of the seas," is forever linked with ocean navigation and transatlantic communication as the names of Walter Reed and Henry Carter are with the development of preventive medicine. John W. Mallett, Thomas Jefferson Page, Elisha Kent Kane, Charles S. Venable, Benjamin S. Ewell, William Morris Fontaine and Jed Hotchkiss are other and less widely known Virginians who la-

bored to advance science during the nineteenth century.

William Barton Rogers, who became the first president of the American Association for the Advancement of Science when this society was formed in 1848 and whose memory is to be honored at the December meeting of the association, was appointed in March, 1835, to be the first state geologist of Virginia. He was teaching at the College of William and Mary, and he transferred to the University of Virginia, where he served as professor of natural philosophy until 1853. The failure of the Virginia General Assembly in 1841 to continue its appropriation for the Geological Survey resulted in the abolition of his office as state geologist, but as university professor he continued his studies in the fields of physiography, mineralogy, petrology, economic geology, stratigraphy and paleontology.

He left the University of Virginia to go to Cambridge, Massachusetts, where he became the first head of the Massachusetts Institute of Technology. The reports that he published and the papers he left behind him when he went to Massachusetts, which were edited by Major Hotchkiss, war-time topographic engineer for General Stonewall Jackson, and which appeared in the six volumes of "Geology in Virginia" between 1880 and 1885, led to a wider appreciation of the scientific possibilities and opportunities of the Old Dominion.

William B. Rogers and his brother, Henry Darwin Rogers, made extensive field observations in the Virginia Appalachians. Professor Rogers died in 1882, and eleven years later there was built at Saltville, in the heart of these uplands, the first plant of the Mathieson Alkali Works. This was a forerunner of the great industrial movement that has spread through Virginia during the first three decades of the twentieth century.

From small beginnings there has been swift development, and now almost every phase of modern scientific industry can be found within the Old Dominion. The banks of the James, the York and the Rappahannock, where generations of planters lived on their broad acres, are now fringed with plants for the manufacture of paper, of cellulose fabric and other products of industrial chemistry. Inland villages have boomed and mountain valleys have taken on unaccustomed activity almost over night. And behind each step in this expansion of industry is a story of long and careful scientific investigation, most of it carried on in secret and protected by patents.

A century has gone by since Dr. Rogers founded the Virginia Geological Survey, but it has been largely through the efforts put forward by this agency since its revival in 1908 that the mineral wealth of the Old Dominion has become known. Under the direction of the late Thomas L. Watson, of Wilbur A. Nelson and now of Arthur Bevan, the Geological Survey has sought to discover the important facts concerning the geology and mineral resources of the commonwealth and to publish accurate reports of its findings.

During recent years about forty different kinds of rocks and minerals have been quarried and mined in Virginia for commercial use, and through the last quarter century the mineral production of the state has totaled roughly one billion dollars. In addition to the publication of reports the Virginia Geological Survey has for the last twenty-five years cooperated with the Federal Government in an extensive program of topographic mapping.

When Jefferson established his university he planned for the teaching of astronomy and went so far as to prepare for an observatory on top of a little mountain west of Charlottesville. But there was no money to carry out the project nor could the needed amount be raised

when it was proposed, in 1866, to bring Commodore Maury from the Virginia Military Institute to the university as professor of astronomy.

Leander McCormick, son of Robert and brother of Cyrus McCormick, presented to the university a refracting telescope of 26 inches aperture and 32½ feet focal length which was, when the observatory was opened in 1883 with Dr. Ormond Stone as director, the largest and finest in the whole world. This distinction it held for only a few years, but it remains to-day the largest refractor in the eastern United States.

THOMAS JEFFERSON, BY THE LATE KARL BITTER

Twenty-five years ago, in 1913, Dr. S. A. Mitchell, came from the Yerkes Observatory and from Columbia University to succeed Professor Stone. At the Yerkes Observatory he had been engaged in the measurement of the distances to the stars by photography and he began plans to continue this work at Virginia. The photographic work was started at the McCormick Observatory in the autumn of 1914 and since then more than 41,000 plates have been taken. In this project Dr. Mitchell has had the support of such colleagues on the staff as Dr. Charles P. Olivier, now director of the Flower Observatory; Dr. Harold L. Alden, now in charge of the Yale Observatory in Johannesburg, South Africa; Dr. Peter van de Kamp, now director of the Sproul Observatory, and of his present associates, Dr. Alexander N. Vyssotsky,

Dr. Dirk Reuyl and Dr. C. M. Anderson, Jr.

Although about ten of the great observatories are engaged in the project, the McCormick Observatory is one of three observatories measuring the greatest number of stellar distances. At the fall meeting of the National Academy of Sciences Dr. Mitchell reported on the determination of the distances of 1,350 stars by the trigonometric method. All bright stars in the sky north of 20° south declination and irrespective of color have had their distances measured. The present working program of the McCormick staff consists chiefly of measuring faint stars of large proper motions.

From the large collection of photographs made by the 26-inch refractor the proper motions of 18,000 stars have been determined and published. From this abundant material there was found the motion of the sun with respect to stars of different magnitude and different color, the rotation of the galaxy in 200,000,000 years and the constants of the precession of the equinoxes. It has also been possible to determine the magnitudes of 8,000 sequence stars to be used as comparison stars in determining the brightness of 450 variable stars of long period.

Dr. Mitchell is perhaps the world's foremost observer of solar eclipses, and he has traveled many thousands of miles to observe ten total eclipses. He had served for seven years as president of the commission on parallaxes and proper motions of the International Astronomical Union when, in 1935, he gave up this office to become president of the commission on eclipses. He was reelected head of this commission at the last meeting of the union in Stockholm.

An important new apparatus for attacking problems in chemistry, physics, biology and medicine is the ultracentrifuge developed in the Rouss Physical Laboratory of the University of Virginia by Dr. Jesse W. Beams. He and his associates have found that they can spin these rotors as fast as 21,000 revolutions a second, and that their speed is limited only by the strength of the material from which they are made. Compressed air and hydrogen have been used to spin the rotors until the centrifugal force generated is 8,000,000 times gravity. More recently electrical force has been used for supporting and spinning these rotors.

When spun inside a vacuum chamber the ultracentrifuge is not subjected to friction from the air, and because no heat is generated materials being centrifuged inside the rotors do not undergo remixing. Dr. Beams is using this apparatus for the separation of isotopes, and in the University of Virginia Biochemistry Laboratory Dr. Alfred Chanutin and his assistant, Dr. Victor Masket, have applied the ultra-centrifuge to researches in viruses, hormones and enzymes. Men trained at the University of Virginia and instruments developed there have found their way into leading scientific and industrial laboratories in this and other lands.

In the Rouss Laboratory Dr. Leland B. Snoddy has been making studies of high-voltage electrical discharges in gases. He began by studying these phenomena in the laboratory, but he has included a study of lightning, and during the last two summers he has made visits to Churchill, in the upper Hudson Bay country, where he has extended his investigations to the aurora.

Seven Virginia colleges and universities are cooperating on a chemical research project that has recently been started under the supervision of Dr. John H. Yoe, of the University of Virginia, who is engaged in a search for new organic reagents for use in inorganic analysis and in studying the relationships between the molecular structure of organic compounds and their analytical reactions.

Cooperating in this work are Professors W. J. Frierson, of Hampden-Sydney

College; Lucius J. Desha and John R. Taylor, of Washington and Lee University; J. W. Watson and F. H. Fish, of Virginia Polytechnic Institute; I. A. Updike, of Randolph-Macon College; William E. Trout, of Mary Baldwin College, and A. R. Armstrong, of the College of William and Mary. Already about 1,200 compounds have been studied, and more than 150 separate tests have been made with each compound.

Another cooperative project in chemistry, one that has been under way for several years and that has attracted wide-spread attention, is the intensive endeavor to find new organic substances with analgesic properties but without habit-forming effects. This investigation has been supported by the National Research Council and has been directed by Dr. Lyndon F. Small, who this year has sixteen men working with him at the University of Virginia. Scientists at the University of Michigan and in four departments of the Federal Government are joining hands in this work.

In the field of biology the University of Virginia carries on activities at three separate locations. Within the Biological Laboratory at Charlottesville the study of flatworms being made by Dr. W. A. Kepner and his associates has resulted in the discovery of many new species. At the Norfolk Division of the College of William and Mary, Dr. E. Ruffin Jones is at work on a correlated study of marine flatworms.

At the Blandy Experimental Farm, which the university operates near Boyce, investigations into the cytogenetics and the cytotaxonomy of various groups of plants are being conducted by Dr. Orland E. White and a group of research fellows. Studies are also in progress on the longevity of plants, the prevalence of variations in wild plant species, and on the relation of geographical distribution, mutation and the resistance of plants to low temperatures.

For nine summers a Biological Station has been conducted at Mountain Lake under the direction of Dr. Ivey F. Lewis.

WEST LAWN OF THE UNIVERSITY OF VIRGINIA

SHOWING THE FIRST OF THE ORIGINAL PAVILIONS DESIGNED BY THOMAS JEFFERSON FOR FIRST FACULTY MEMBERS, WHO LIVED UPSTAIRS AND TAUGHT DOWNSTAIRS. STUDENTS HAVE LIVED IN INDIVIDUAL ROOMS ALONG THE COLONNADE FOR MORE THAN A CENTURY.

THE ROTUNDA, DESIGNED BY THOMAS JEFFERSON
WHO ADAPTED IT FROM THE ROMAN PANTHEON TO BE THE CENTRAL BUILDING OF HIS "ACADEMICAL VILLAGE," THE UNIVERSITY OF VIRGINIA.

Students and investigators from the southern states and from some eastern universities are in residence during ten weeks each summer. Dr. Paul R. Burch, of East Radford State Teachers College, is conducting a survey of the animal life of Virginia, especially of the Alleghany region. Dr. L. R. Cleveland has published an investigation of the symbiotic flagellates of the wood roach, an important study in relation to termites and their activities. Dr. D. R. Hostetter, of Harrisonburg, is completing an exhaustive study of the Carolina junco, perhaps the most complete account of the life history and habits of any southern bird. Other studies of wide variety are in progress, including the ichthyology of the James River and the Ohio River drainage areas, which lie on either side of the divide at Mountain Lake.

In the commonwealth there are two centers for medical research, the Department of Medicine of the University in Charlottesville and the Medical College of Virginia in Richmond.

At the risk of making this seem a catalogue of University of Virginia activities a few medical projects must be mentioned. Probably the best known to members of the American Association for the Advancement of Science is the visual and photographic study of living nerve and muscle cells by Dr. Carl C. Speidel, who received the $1,000 prize of the association at its New Orleans meeting for his initial investigations in this field. Other medical studies include investigations of the ductless glands in the Physiological and in the Biochemical Laboratories, surgical work on pressures developing within the brain and spinal cord, the control of blood pressure, and experimental studies of allergy and allergic diseases. Others, equally important, might be named, but space does not permit.

Among many of the important contri-

butions to medical knowledge made by members of the staff of the Medical College of Virginia may be listed: the extensive work by the Department of Bacteriology on the liquefaction of gelatin by bacteria and on the isolation and identification of pathogenic fungi and the studies on insecticides, the glycols and the standardization and action of digitalis preparations by the Department of Pharmacy. The composition of alveolar air and factors affecting it as well as the physiology of muscular contraction and photosensitization have been attacked with considerable success in the Department of Physiology.

In other departments at Richmond work has been carried out on the effect of various stimulations on the sympathetic nervous system, the prevention of liver damage from the administration of various toxic substances, the interrelation and dependence on each other of the lung, blood, heart and certain secretory organs, especially their mutual chemical interdependence and regulation, and also the experimental production of lipoidoses, botriomycosis and certain types of nephritis.

In the clinical fields due emphasis has been given to the improvement of the routine care of patients, as well as to the investigative side of clinical problems. Much interest has been shown in the discovery by Minot and Murphy in the treatment of pernicious anemia, and a considerable number of original observations have been made and reports of these have appeared in national journals. In the last several years the investigative work has concerned itself with the physiological adjustments occurring in anemias, arteriovenous fistulae, in pregnancy and in other conditions which throw an excessive load on the cardiovascular apparatus. The availability of a large amount of clinical material in the Negro race has stimulated research in comparative physiology and the variations of the reaction to disease in the Negro.

The Medical College of Virginia has a large hospital for colored patients, and this has provided the Surgical Department with an exceptional opportunity to study the diagnosis, treatment and the prognosis of heart wounds.

In the Department of Dentistry considerable study has been carried on in regard to the histological changes in teeth due to plastic filling materials. Reports have been published on the subject showing the varying effects of different types of fillings on the histological structure of the teeth. In the field of prosthetic dentistry an effort has been made to show that a greater understanding of the biological laws of the dental system is necessary in the construction of artificial restorations. Certain natural forces that are of direct importance to the prosthodontist originate in the dental system and the fact that these forces arise from living tissue gives to this work a biological aspect.

Within scientific laboratories of Virginia there are more than a thousand workers, most of them with college or university affiliations. Undergraduate or professional instruction constitutes the most important work of the majority of them, but almost every one finds opportunity for specialized investigations. To list merely the names and research activities of these would be impossible, but some typical projects should be considered.

At the Virginia Polytechnic Institute the Department of Chemical Engineering is at work on several problems in the field of farm chemurgy. Two studies on soybeans are in progress; an experiment is being made in the use of the entire cotton plant, stalk, leaves, boll and lint, as a basis for synthetic lumber, improved methods of drying and curing tobacco are being investigated, and laboratory information on the utilization of peanut hulls is being sought.

The Virginia Agricultural Experiment Station, with headquarters at Blacksburg

and with ten sub-stations scattered over the commonwealth, has a staff of some 60 scientists at work on 150 major studies ranging all the way from the control of destructive tobacco blue mold to the substitution of lard for butter in making cakes, from flower garden soil studies to methods of controlling the ever-present codling moth.

Dr. A. D. Pratt, in the Dairy Husbandry Department at the Virginia Polytechnic Institute, has found that pasteurization of milk in an atmosphere of carbon dioxide prevented destruction of vitamin B_1 and produced a high vitamin C content. The blue mould or downy mildew fungus, which wiped out seedling tobacco plants over a wide area in 1932, 1933 and 1937, has been conquered by plant pathologists under Dr. S. A. Wingard, working in cooperation with Duke University. Animal pathologists have been tracing the life history of the black fly, which breeds in the larger streams of southwest Virginia and whose bite transmits a disease which has taken heavy toll in the turkey industry. At one sub-station the varying tolerance to arsenic of codling moth larvae from sprayed to unsprayed orchards is being studied.

The Virginia Cooperative Wildlife Research Station, being conducted under the direction of Dr. I. D. Wilson, head of the department of biology at the Institute, is under the joint auspices of the federal and state governments and of the institute. It is one of eight wildlife stations in the United States. The wild turkey is the center of a study which is considering food, cover, diseases and methods of restocking. Deer, quail, grouse and other game birds and animals are also being observed by C. O. Handley, A. B. Massey, C. F. De La Barre and others.

The Engineering Experiment Station at the Virginia Polytechnic Institute conducts investigation in professional and industrial fields and has recently completed an extensive analysis of the rainfall and stream flow of Virginia in which use has been made of data which has been accumulated over half a century or more.

Dr. Donald W. Davis, of the College of William and Mary, has been for years breeding balsam in carrying forward a thoroughgoing test of the Mendelian laws of heredity. In his investigation of behavior of species he has found most striking variations in flower colors.

At Washington and Lee University one of the most interesting projects is the study being done by the Geological Department on the origin of the Natural Bridge and of the various rocks in the Shenandoah Valley, including deposits of heavy minerals in these rocks. Dr. H. M. Stowe and Dr. E. C. H. Lammers have also been engaged in summer work on Rocky Mountain structural geology.

In the Biological Department at Lexington some workers have been studying the life history and control of the tarnished plant bug in celery, while others have been investigating mineral metabolism in experimental tuberculosis. In the Chemical Department work has been in progress for several years on textbook preparation and verification, and two volumes have recently been published.

This survey of the scientific investigations now going forward within the Old Dominion is all too incomplete. It is not intended to be a comprehensive coverage of the subject, but rather to show, by pointing first here and then there, that the research spirit has permeated every corner of the commonwealth and to give an earnest of the warm and understanding welcome awaiting those who come to Virginia for the 1938 meeting of the American Association for the Advancement of Science.

THE RECENT HURRICANE IN NEW ENGLAND[1]

By I. R. TANNEHILL

CHIEF OF THE MARINE DIVISION, U. S. WEATHER BUREAU

I

THE hurricane that wrought such devastation in New England on last September 21 originated as a tropical cyclone about 12 days before, presumably in the region of the Cape Verde Islands, thence traveled westward, as storms of this origin do, to near the West Indies, then curved northward, crossed New England, and faded over eastern Canada. Although this great storm, during its charted history, traveled about 3,000 miles, its destructive effects were confined almost altogether to Long Island and the New England States. Such storms have occurred before; some of them have sent many ships to the bottom in the open sea, but the modern steamship, with information and warnings by radio, is seldom in serious danger. Boats along the coast, seaside structures and property in the adjacent interior can not be adequately protected from the fury of a great hurricane. Its destructive effects are owing to the winds, which come in vicious gusts, to the torrential rains, which cause floods in the rivers, and to the rise of the sea along the coasts due to the driving force of the winds and the reduction in atmospheric pressure.

How such storms originate is not definitely known. Certain conditions which exist almost universally over the surface of the ocean during the formative period, namely, frequent showers, light winds and warm, moist air, are thought to be necessary for their development. These conditions are frequently found in or near the doldrums, which is the belt of calms lying along the heat equator between the trade wind systems of the two hemispheres. Observations during the birth of a tropical cyclone show that unsettled, showery weather with a

[1] The photographs on pages 42, 44, 45, 48 and 49 have been furnished through the courtesy of Carl Zeiss.

Photo by Dr. H. C. Sands

THE COLLAPSE OF BUILDINGS SHOWN ABOVE IS TYPICAL OF THE FORCE OF THE WIND NEAR CHARLESTOWN, RHODE ISLAND.

SURF AT WOODS HOLE, MASS.
TWO HOURS BEFORE THE STORM REACHED ITS MAXIMUM INTENSITY.

gradual inflow of air takes place over a relatively large area, usually involving thousands of square miles. Because of the effect of the earth's rotation, the winds, which would otherwise flow directly toward the center, are deflected to the right, in the Northern Hemisphere (to the left in the Southern), and a cyclonic wind system is thus established.

Obviously, a complete explanation of the genesis of a tropical cyclone must rest upon a knowledge of what takes place in the atmosphere above the earth's surface; the information available at present is inadequate for this purpose.

Some of these incipient disturbances quickly grow into violent tropical storms, others increase in force more slowly, while many of them do not develop anything more than mild wind systems with unsettled, squally weather.

Soon after its formation in the tropics, the cyclone begins to move. The generally accepted explanation is that the tropical storm moves with the general drift of the air masses in which it lies. In tropical regions this general drift is toward the west, but as the cyclone arrives in higher latitudes, usually about 20° to 30° from the equator, it is likely to turn more abruptly away from the equator, slowing somewhat at the turn and then progressing more rapidly to higher latitudes, but there have been numerous exceptions; many of them have continued on a westerly course without any recurve.

Various names have been given to tropical cyclones in different parts of the world. Those of the North Atlantic Ocean are generally called West Indian hurricanes. In the Bay of Bengal they are called cyclones; in the western North Pacific Ocean they are known as typhoons.

West Indian hurricanes usually diminish in force on moving out of the tropics, but there have been some notable exceptions, of which the New England hurricane of last September is an outstanding example. In the present century 13 cyclones of tropical origin have crossed New England and about as many others have traversed the ocean within 50 miles of Nantucket. Nearly half of them had developed full hurricane inten-

Photo by C. A. Fuller

IN THE VICINITY OF BROCKTON, MASSACHUSETTS

TORN FROM ITS MOORINGS, THIS BOAT WAS CARRIED AGAINST THE TREES BY WIND AND WAVE.

sity before leaving the tropics. Nevertheless, it is necessary to go back more than 100 years to find a hurricane in New England which closely approaches the storm of last September in destructive power.

II

The history of hurricanes in New England reveals some of the advances that have been made in detecting cyclones in their early stages of development and in following their movements from day to day. Perhaps the first of these visitations, of which there is any record, was the gale of September, 1635. Although this storm undoubtedly was of tropical origin and of great intensity, the only noteworthy result was widespread destruction of trees, there being then but few settlers.

No suspicion could have been in the minds of the scientists of that day that the hurricane is a sort of great whirlwind about a center of low atmospheric pressure, for the barometer was not invented until 1643 and hurricanes were not treated as whirlwinds until about 1650. Nearly two centuries passed before their nature was satisfactorily demonstrated.

Severe hurricanes visited New England in 1788 and 1815. The latter, known as the "Great September Gale," was probably equal in destructive power to the hurricane of September, 1938. Newspaper accounts of this storm were preserved, and were published in 1842, and from them the path of the storm can be accurately determined from the West Indies to the New England coast.

At the time of the September hurricane of 1815, Oliver Wendell Holmes was 6 years of age. His poem, "The September Gale," refers to this hurricane; the following is an excerpt:

> It chanced to be our washing-day,
> And all our things were drying;

Photo by Maxwell Frederic Coplan

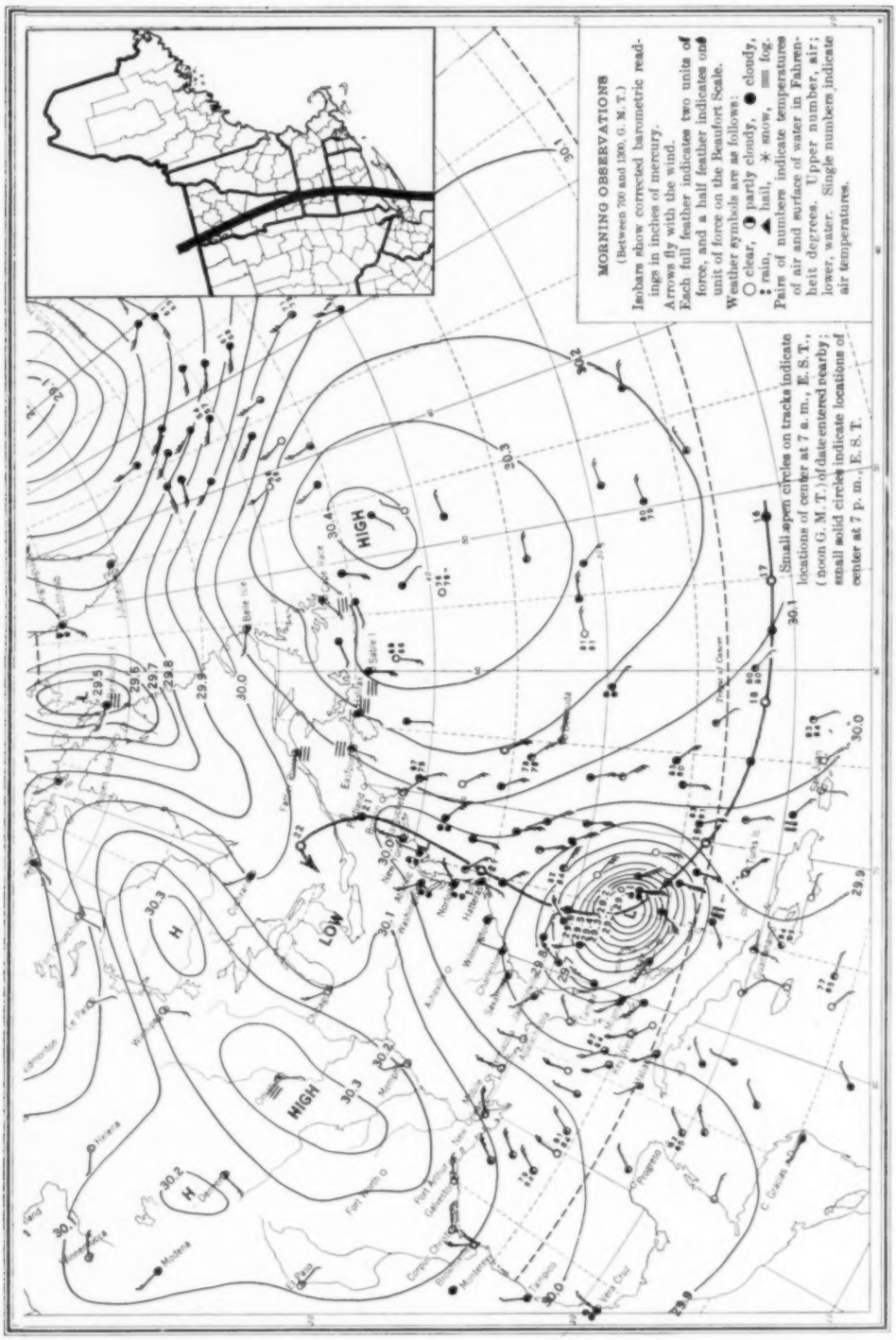
HAVOC WROUGHT TO BOATS ON THE EASTERN SHORE OF MASSACHUSETTS.

The storm came roaring through the lines;
And set them all a flying;
I saw the skirts and petticoats
Go riding off like witches;
I lost, ah! bitterly I wept,—
I lost my Sunday breeches!

The course of another September hurricane, in the year 1821, was very similar to that of the recent storm. It crossed Long Island, moving northward, its center passing to the westward of New Haven. In traveling over the devastated area, a saddler by the name of William C. Redfield (first president of the American Association for the Advancement of Science, and grandfather of the late William Cox Redfield, Secretary of Commerce in Wilson's administration) noticed the direction in which the fallen trees were lying and concluded that the storm was a great whirlwind. However, he did not publish his ideas until 1831, when Professor Olmstead, of Yale University, induced him to write an article for the *Journal of Science and Arts.*

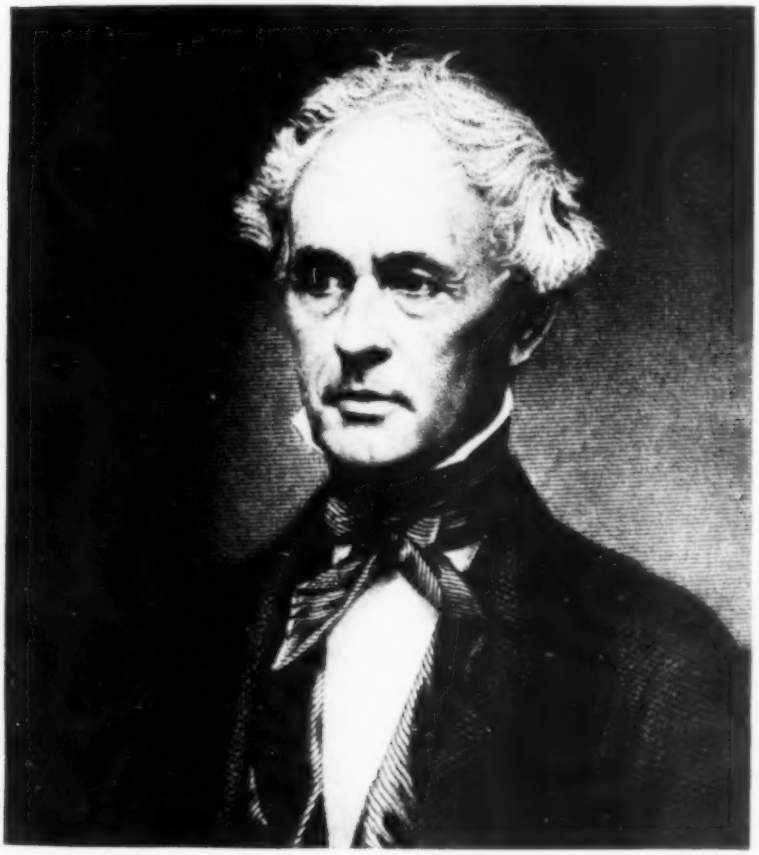
Under the stimulus of Redfield's discovery, tropical cyclones of the West Indies were studied, from the data available in the logs of sailing ships, and the paths of many of them were charted during the following quarter of a century.

The next severe hurricane in New England occurred in September, 1869. It was destructive over a path about 60 miles wide. However, there was no warning of its approach, as the national weather service was not established until 1870. The first cautionary warning of a hurricane approaching New England was issued in 1873. This hurricane was traced from the vicinity of the Cape Verde Islands westward across the Atlantic. Recurving between Bermuda and Hatteras, the storm took a northerly course and crossed the coast line of Nova Scotia, where it was very destructive. More than 1,200 vessels were lost. As the hurricane approached the Atlantic coast, cautionary warnings were



WEATHER MAP OF NORTH ATLANTIC OCEAN

FOR SEPTEMBER 20, AND THE TRACK OF THE HURRICANE FROM SEPTEMBER 16–22. INSET: PATH OF THE CENTER OF THE HURRICANE THROUGH



WILLIAM C. REDFIELD

FIRST TO DISCOVER THE WHIRLWIND CHARACTER OF THE HURRICANE. REDFIELD WAS ALSO THE FIRST PRESIDENT OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

WEATHER MAP OF NORTH ATLANTIC OCEAN FOR SEPTEMBER 20, AND THE TRACK OF THE HURRICANE FROM SEPTEMBER 16-22. INSET: PATH OF THE CENTER OF THE HURRICANE THROUGH THE NEW ENGLAND STATES

hoisted at Cape May, N. J., New York, N. Y., and New London, Conn.

With the advent of radio communication, it became possible to follow a hurricane in its development and movement over the ocean and to give more accurate notices of its approach. There have been noteworthy achievements in the warning service, which include international cooperation, the voluntary assistance of seamen of all nationalities and precise coordination of collecting, mapping and broadcasting the information.

III

The first charted position of the hurricane of September, 1938, was at 21° north, 53° west, late on the 16th. Observations on the morning map of September 13 gave some evidence of cyclonic circulation near 19° north, 37° west, hence the storm probably originated near or south of the Cape Verde Islands. Many hurricanes of August and September have been traced to that region, but owing to the small number of ships over the vast ocean area between the Cape Verdes and the West Indies it is impossible to establish definite tracks for many that appear to have originated there. Positions far to the eastward have been determined after reports arrived by mail from meteorological stations on the Cape Verde

Photo by C. A. Fuller

TREES AND POLES UPROOTED BY THE HURRICANE NEAR BROCKTON, MASSACHUSETTS.

Islands or from steamers in the neighborhood.

Over waters near the Atlantic coast it is usually possible to plot the observations taken by ships in a hurricane with a delay of only about one hour in transmission by radio to the shore station and by telegraph to the Weather Bureau Office. Occasionally a ship is in a position to send a radio report which enables the meteorologist to determine the approximate location of the center of a

Photo by C. A. Fuller

A BUILDING IN THE VICINITY OF BROCKTON DESTROYED BY THE FORCE OF THE WIND.

hurricane far to the eastward of the West Indies within an hour or two after the observation is taken on shipboard. The record in that respect was the report of a hurricane from a ship at 17° 30′ north, 41° 18′ west, on September 28, 1936. In another instance, nearly as far to the eastward, a hurricane was located definitely by a radio report from 17° north, 48° 15′ west, on September 10, 1928.

Usually the movement of hurricanes far out in the Atlantic between the Cape Verdes and the West Indies is toward the west-northwest or west by north in early stages, but the majority recurve to the northwest, north or northeast before reaching the West Indies; a fraction of them continue on a westerly course until they reach the West Indies or the South Atlantic States or recurve to higher latitudes while traversing the waters between the Bahamas and Bermuda. A few of them have been of large diameter and great intensity on reaching the longitude of Puerto Rico. In recent years there have been some notable examples, in particular the hurricane of September, 1936, which was centered to the southwest of Bermuda on the morning of the 16th with strong winds (30 miles or more per hour) over an area with a diameter of nearly 1,000 miles. It crossed extreme eastern North Carolina but recurved sharply to the northeast with its center at sea a short distance from Nantucket. When the hurricane of 1938 passed between Bermuda and the Bahamas, the area of strong winds (30 miles or more per hour) was about 500 miles in diameter.

Photo by Maxwell Frederic Coplan

FRONT WALL OF HOUSE TRANSPORTED BY THE WIND TO A NEW LOCATION ON THE HIGHWAY.

The height of the barometer at the center of the recent hurricane was probably about 28 inches, or slightly lower during most of its course at sea. This is about the average for intense hurricanes of large diameter. Much lower readings have been recorded, however, the world's lowest being 26.19 inches in a typhoon east of the Philippines. In the United States the record is 26.35 inches on the Florida Keys in September, 1935.

On recurving to the northeastward and moving to higher latitudes, West

Indian hurricanes usually have a more rapid progressive motion (20 to 30 miles an hour) than they do in the tropics, where it averages about 12 miles an hour. Nevertheless, the recent hurricane was abnormal in that respect. In 12 hours it moved from a position off Hatteras to southern Vermont and New Hampshire. Over this part of its course its rate of progress was about 50 miles an hour.

On the right side, looking forward along the line of progress, the winds of the hurricane are directed more or less along the line of progression, so that their velocity in this portion of the storm is a combination of the two motions. On the left side, the forward movement is subtracted, more or less, from the wind system of the hurricane. Because of its extraordinarily rapid movement toward the north, the recent New England hurricane had destructive winds far to the eastward of its center, 100 miles or more, while there was relatively little damage to property on the west side.

Wind velocities were high; 82 miles an hour at Block Island, R. I., 87 at Providence, R. I., and 121 at Blue Hill, Milton, Mass., near Boston. These were sustained winds, measured for periods of five minutes; velocities for shorter intervals were much higher, as evidenced by measurements ranging from 173 to 183 at Blue Hill Observatory. Higher velocities have been recorded in hurricanes, notably five-minute velocities reaching 150 miles an hour at San Juan, P. R., in September, 1928. In many instances the wind-measuring instruments have been wrecked or the supporting structures have been thrown down prior to the full force of the storm, hence there is only fragmentary information as to the maximum velocities of hurricane winds.

Ordinarily, the tide on the coast near the hurricane center and to the right of it is considerably above normal as the storm moves inland. In some instances it reaches the proportions of a "tidal wave" or "storm wave" which is disastrous to life and property. On the coasts of India and China the loss of human life has been placed at 50,000 or more in a single storm. Exceptionally large losses of life were reported at Backergunge, India, in 1876 as the result of a tropical cyclone and storm wave, estimated at 200,000, and at Haifong, China, in 1881, estimated at 300,000.

In the United States, the greatest disasters of this source were in the Galveston hurricane of 1900 with loss of life reported to be approximately 6,000 and in the Florida hurricane of 1928 with nearly 2,000. In the recent hurricane in New England, the loss was about 600.

The areas of Long Island and New England, over which the recent hurricane moved, are much more densely populated than tropical and subtropical regions subject to such storms, except parts of India, China and Japan, and property values per capita are very much higher. Conservative estimates of the property damage on Long Island and in New England place the total between two hundred and fifty and three hundred and thirty million dollars. Indeed, there is little doubt that the value of property destroyed by wind and water attending the New England hurricane of last September was greater than that recorded in any other tropical cyclone in the world's history.

FAR AWAY AND LONG AGO

By EDWARD W. BERRY

PROVOST, THE JOHNS HOPKINS UNIVERSITY

I HAVE borrowed the title from Hudson's delightful recollections of his boyhood life on the illimitable acres of a Pampean Estancia because it is so appropriate a one under which to describe something of the life in Patagonia quite as far away and almost infinitely longer ago in which I have had a small part, even though that part was in the nature of what may be called retrospective propheey.

A long experience has convinced me that geography is not one of the native accomplishments of our great republic. Perhaps its very size works against this, for it is easy to imagine that the educated class at least in a half-pint country would have a better knowledge of the rest of the world. At any rate my friends can never understand why I froze under the equator, why I did not burn wood in the Bolivian Andes, or why I much prefer the climate anywhere on the perimeters of the Caribbean to that of Baltimore.

I have been trying for over a score of years as opportunities offered to find out something of the floral history of South America. Of late years through the kindness of former students and friends and officials of surveys there has been no lack of material. Quite the most extensive collection was sent me a few years ago by the Argentina Survey through the interest of one of the younger members of its staff—Señor José Ramon Guiñazú. The results of this study were published last July,[1] and the editor has asked me to prepare a sort of abstract of this work for the readers of THE SCIENTIFIC MONTHLY.

[1] Geological Society of America Special Pub. No. 12.

Patagonia is the name of a somewhat vague region which has no political reality and which you will not find on a modern map. Formerly it was used for the antipodean part of South America shared by the republics of Argentina and Chile. As used in the present connection it comprises the three territories of Rio Negro, Chubut and Santa Cruz, extending from the crest of the Andes to the Atlantic Ocean and from about 40° South Latitude to the Straits of Magellan. Although it tapers off toward the Southern Cross and does not look very big on ordinary small-scale maps its area is greater than any European country except Russia.

The climate is about as bad as it is possible to imagine. There have been many descriptions of the inhospitable character of the treeless wastes and the depressing effect of the constant winds. Darwin writes of it in a letter to Henslow in 1832, "I had hoped for the credit of Dame Nature, that no such as this existed."

In his Journal during the ascent of the Rio Santa Cruz we find him writing: "The complete similarity throughout Patagonia is one of its most striking characters. The level plains of arid shingle support the same stunted and dwarf plants; and in the valleys the same thorn-bearing bushes grow. Everywhere we see the same birds and insects. Even the very banks of the river and the clear streamlets which entered it were scarcely enlivened by a brighter tint of green. The curse of sterility is on the land, and the water, flowing over a bed of pebbles, partakes of the same curse."

To be sure this was the reaction of a

homesick lad, and the country is not as bad as it is painted—some people even grow to be fond of it, although I have never had the good fortune to meet such a one. However, like the human derelict who asks for alms and assures you that he has seen better days, so it is with Patagonia in the long ago. If we look beneath the surface of the barren ash beds or examine the barrancas, there comes to light the manifold evidence of a glorious past—not simply the evidence of a single golden age, but of a long succession of great eras during which Patagonia was the home of a greater variety of strange beasts than any other region on the globe, either past or present. There were great beasts that looked like elephants or rhinoceroses that were not elephants or rhinoceroses. Even the familiar evolution of the horse was paralleled in quite an unrelated stock of mammals so that the clerical story of how Noah named the various animals would work out very badly in Patagonia. The story goes that the explanation of the naming of the elephant, the lion and the tiger was exceedingly simple. Noah merely christened them thus because they looked like an elephant or a lion or a tiger.

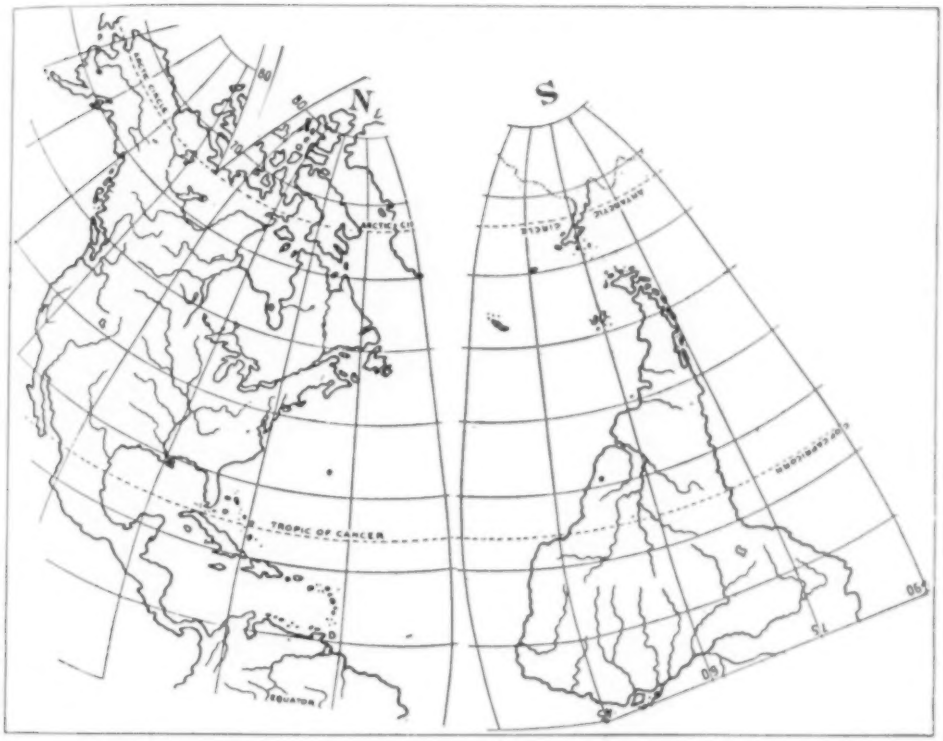
If this method had been utilized in the naming of the fossil fauna of Patagonia, Noah would have been obliged to call the Pyrotherium an elephant, the Astrapothere a hippopotamus, the Prototherе a horse, some of the strange marsupials lions or tigers, and the Toxodont a rhinoceros. At any rate, as Scott well says, the Tertiary mammals of Patagonia are bewildering as if they belonged on another planet.

Naturally this maze of herbivorous animals which supported the host of carnivorous marsupials which preyed on them required food, but until a few years ago nothing was known of the vegetation of Patagonia in Tertiary times and the vertebrate paleontologists were inclined to paint a picture of treeless grassy plains, which is somewhat overemphasized and does not agree with the subsequent discoveries of the fossil flora.

In general it may be said, at least in so far as the angiosperms or flowering plants are concerned, that in the late Cretaceous, those of Patagonia were sufficiently like those long known from the northern hemisphere to class them as cosmopolitan types which had not been cut off by geographical obstacles from the common reservoir which was the region of dispersal of Upper Cretaceous floras. Some authorities think this center of radiation was in the Arctic region, others locate it in central Asia and still others think that it was in tropical uplands. The evidence on which these opinions are based is neither too clear nor at all conclusive.

Following the late Upper Cretaceous floras in Patagonia is a second stage, the age of which I have called Paleocene. This is a broad-leafed dicotyledonous flora indicative of rather mild climatic conditions and which appears to stand in an ancestral relationship to what I have called the Eogene flora. This last is a rather wide-spread flora, perhaps not everywhere of exactly the same age, dominated by small-leafed trees of which a great variety of beeches are the dominant element. This has long been known from the Straits of Magellan region, from Seymour Island on the coast of Antarctica and from various localities in Patagonia, in Chubut and Rio Negro territories, or northward to about latitude 40° S. This is a temperate flora, indicating a somewhat harsher climate than the Paleocene flora which preceded it, or what I have called the lower Miocene flora which succeeded it.

The last, which is the most abundant and varied of all, comes from a number of localities in all three of the Patagonian territories from Rio Negro on the north to Santa Cruz on the south, from



CORRESPONDING LATITUDES IN NORTH AND SOUTH AMERICA

the Rio Pichileufu about 30 miles east of Lago Nahuel Huapi (Long. 71° W) on the west to the Valcheta basin (Long. 66° W) on the east. Thus it extends through 5 degrees of longitude and through 7 degrees of latitude, and hence it overlaps the Eogene floras southward some 10 degrees.

This assemblage is most prolifically represented at the Rio Pichileufu locality. It comprised over 125 different arborescent forms: a grass related to one of the modern Pampas grasses (Chloris), three striking kinds of ferns, one of which is a tree fern, and a very abundant cycad. After some restricted comments on the more spectacular plants I will pass to some general conclusions.

One of the more abundant finds was a well-marked species of Ginkgo. The fascinating history of this genus has often been discussed both popularly and scientifically. It is commonly considered Asiatic; Darwin called it a living fossil because its sole surviving species was preserved from extinction in the temple gardens of eastern Asia, which may have been the only region where it survived to be contemporaneous with the human race, although, as a matter of fact, no wild species have ever been authentically reported. Ginkgo is a very ancient type which had attained a wide distribution by Jurassic time, at the latest. The discovery of a Tertiary species in Patagonia completes the list of the continents on which Ginkgo was a member of the Tertiary flora, and on many of these—for example, Europe—it was present as late as the Pliocene.

Another interesting find was many twigs and cone scales of a species of Araucaria—the Chilean or Norfolk Island pine or monkeypuzzle of modern bota-

Photo by José Ramon Guiñazú

THE FOSSIL PLANT LOCALITY ON THE RIO PICHILEUFU (AT THE RIGHT). IN THE FOREGROUND IS MORAINIC MATERIAL.

nists. In existing floras this genus is confined to southern Brazil, a relatively small area in southern Chile, and the Australian region. If nothing were known of its geologic history this modern distribution would afford a strong argument for an Antarctic or at least antipodean center of radiation. But Araucaria is a very ancient type and attained a nearly world-wide range during the Mesozoic era. It was exceedingly common in North America as well as on other continents during Upper Cretaceous time, and its present-day occurrences are readily understood as the surviving representatives of a northern center of radiation and require for their explanation no shifting of continents nor hypothetical land bridges in southern latitudes. Araucaria has been found in Argentina in the Rhaetic deposits and was exceedingly common in that region during the Jurassic, as indeed it was in the earlier Tertiary.

I know of no better illustration than Araucaria for showing the futility of discussions of the origin and distribution of plants by botanists familiar with the plants of only one geological period and that the Recent. A generation ago the plant geographers looking at the existing Araucarias in South America and the Australian region were forced to conclude that it either originated in Antarctica and spread into temperate South America and to New Zealand, Norfolk Island and Australia, or that it originated in one or the other of these places and spread to the others over a trans-Pacific land bridge. The present fossil Araucaria still further illustrates this thesis. Patagonia to-day is practically treeless, whereas the inter-Andean valleys and the south of Chile are covered with dense forests. One of the canons of plant geographers has been that a large number of Argentine plants were introduced from the Chilean region. We now know that a large number of trees, whose descendants have only survived in the wet Chilean region, were present in Patagonia for several mil-

lennia and disappeared from that region in geologically very modern times after the Andes had reared their bulk across the moisture-laden "roaring forties" and thus desiccated Patagonia.

Eucryphia is another genus frequently brought forward as evidence for an Antarctic continent with connections to Australia and Patagonia, or for a trans-Pacific land bridge. Its two existing species, one in Chile and the other in Australia and Tasmania, are nearly 160° apart and are believed by systematic botanists to be closely related. A direct land connection between the two involves a terrific strain on the imagination, and it is difficult to explain why, if there had been such a connection, New Zealand failed to receive its quota. Unfortunately, no fossil species are known except the one from Patagonia that is described in the recent report. The foliage of the two existing species is quite unlike, and it is doubtful whether even if the genus were present in northern fossil floras it would have been recognized, so that I prefer to withhold judgment.

All in all there are 99 genera in 57 families and 28 orders in this early Miocene flora. It is therefore the most extensive known Tertiary flora from South America, being approached only by the flora of the same age from the Arauco-Concepcion coal measures in southern Chile, and that from the Island of Trinidad at the other end of the Andean axis.

Two new genera are recognized Pouterlabatia in the Sapotaceae and Polioexolobus in the Asclepiadaceae. New species are described in the following 15 existing genera which have not hitherto been recognized in the fossil record: Adenocalymma, Azara, Diatenopteryx, Embothrium, Eucryphia, Landolphia, Mascagnia, Myrceugenia, Notaphoebe, Nyctaginites, Remijia, Salacia, Styloceras, Tabebuia and Villaresia.

The largest single genus is Myrcia, with six species and varieties. Next

Photo by José Ramon Guiñazú

RIGHT BANK OF RIO PICHILEUFU VALLEY

BELOW THE FOSSIL PLANT LOCALITY, SHOWING REDDISH RHYOLITIC TUFFS INTERBEDDED WITH LIGHT SANTA CRUZ TUFFS.

come Cupania, with five species; Cassia, with four species; and Sterculia, with three species.

The largest family is the Sapindaceae, with 13 species, followed by the Lauraceae, with 10 species. The Myrtaceae and Rubiaceae have each 8 species; the Anacardiaceae 6 species; the Sterculiceae and Flacourtiaceae 5 species each; the Caesalpiniaceae, Meliaceae, Celastraceae and Apocynaceae 4 species each, and the Proteaceae, Malpighiaceae, Sapotaceae and Bignoniaceae 3 species each.

The cycads, those strange relics of Mesozoic times, are abundantly represented by a species of Zamia, whose living representatives have retreated many degrees to the north. Beside Araucaria, already mentioned, the conifers are represented by Fitzroya, named after Captain FitzRoy, of the *Beagle*, Libocedrus and Podocarpus.

Practically nothing is known of the history of the genus Fitzroya. There is an existing Chilean species and in Tasmania a closely related form which is sometimes made the type of a second monotypic genus. In view of the antiquity of the Coniferales I do not imagine that any student would predicate any sort of a direct land connection between Chile and Tasmania as the explanation of the present-day range of Fitzroya.

The two fossil species of Podocarpus at Rio Pichileufu belong to a genus which, in the modern flora, is as characteristic of the Southern Hemisphere as the pines are of the northern. Its geologic history has never been elucidated, although it appears (as Nageiopsis) in the Mesozoic floras of the Northern Hemisphere and is certainly identified in the Tertiary of Europe. Its presence in South America in all probability dates from the Upper Cretaceous or earlier, and its modern range in South America was undoubtedly conditioned by the last great epeirogenic movement of the Andean region.

There are six genera present in the Rio Pichileufu flora which in the existing flora occur both in South America and in one or several of the Pacific lands far to the west. Thus Embothrium and Drimys are South American and Australian; Laurelia is confined to Chile and New Zealand; and Coprosma is South American and wide-ranging in the Pacific islands to New Zealand and Australia. If the geologic record were more completely known, these facts of present-day distribution might be explained. Both Drimys and Lomatia are represented in the fossil floras of the Northern Hemisphere and appear to have been southern immigrants from some northern center of dispersal. The others may have radiated from some antipodean center, but the evidence is insufficient to establish such a supposition.

About 71 per cent. of the Rio Pichileufu species are new to science, and only 38, or about 29 per cent., have been found at any other localities. Nearly all the species represented elsewhere are found in beds supposed to occur at similar or identical horizons in the Concepcion-Arauco coal measures of Chile, or in Chubut and Santa Cruz Territories in Argentina. The only species that has been found in any other region is *Cassia longifolia*, which has been reported from Ecuador, Venezuela and Trinidad.

One of the most striking features of this flora is its typically American character. Of the genera represented 14 are confined to South America. These are Polylepis, Leptolobium, Icica, Styloceras, Schinus, Schinopsis, Astronium, Villaresia, Diatenopteryx, Azara, Ampelodaphne, Myrceugenia, Adenocalymma, Remijia. There are 26 additional genera which are confined to the Western Hemisphere. These are Zamia, Momisia, Coccoloba, Inga, Cedrela, Tetrapteris, Banisteria, Mascognia, Omphalea, Cupania, Matayba, Banara, Nectandra, Oreodaphne, Acrodiclidium, Eriodaphne (if this is properly segregated

THE RIO TURBIO

VIEWS ILLUSTRATING THE BARRENNESS OF THE PATAGONIAN TERRANE.

from Notaphoebe), Goeppertia, Psidium, Oreopanax, Bumelia, Allamanda, Echites, Tabebuia, Hoffmannia, Coussarea and Rondeletia. It will be noted that these 26 genera, although not confined to South America, are nearly all equatorial American—that is, they are essentially South American genera which have extended their range through the Antilles, or into Central America, or have even reached Florida (Zamia). The genera above enumerated, which may properly be considered essentially South American, number 40 out of the total of 97 known genera—that is, slightly more than 41 per cent.

In addition to this exclusively American element there are 29 genera represented which may be classified roughly as cosmopolitan, or at least as very wide-ranging in modern floras of the warmer regions of the earth, and many of which may as properly be considered American as of any other nativity. Some of these are very large and old genera with a rather continuous distribution. Others are relatively small, such as Cochlospermum or Cephalanthus, with a discontinuous distribution, and no two have precisely the same geologic history. These genera are Goniopteris, Asplenium, Dicksonia, Myrica, Ficus, Anona, Berberis, Hydrangea, Cassia, Dalbergia, Fagara, Salacia, Sapindus, Allophylus, Cissus, Triumfetta, Sterculia, Buettneria, Tetracera. Ouratea, Casearia, Cochlospermum, Myrcia, Ardisia, Styrax, Symplocos, Plumiera, Strychnos and Cephalanthus.

The genera already named account for over 71 per cent. of those represented in the Rio Pichileufu flora.

This leaves 28 genera, or less than one third of the total number (between 28 and 29 per cent.), whose origin may have been different from that of the others or which may have reached the region by a different route. Among these the only one that is often, though wrongly, considered to be Asiatic is the genus Ginkgo.

Besides the new genera and the form genera there remain 11 genera, all

dicotyledons, whose present range is worthy of comment. The lauraceous genus Phoebe, as delimited by systematists, is found in South America and the East Indies and has an outlying species in the Canary Islands. It may be remarked that this apparent wide range is probably to be explained as a taxonomic faux pas and requires no other explanation.

It would be expected that the Rio Pichileufu flora would show some similarity with the African flora if there were any basis for the Wegener and other hypotheses of continental drift. As I have frequently stated, I can see no evidence for these speculations in any of the Tertiary floras of South America. These floras are quite as typically South American as the present floras of that continent. In addition to the wide-ranging genera represented at Rio Pichileufu, whose existing relatives include both South America and Africa in their circumequatorial range, there are but four genera in this fossil flora whose existing relatives are confined to South America and Africa. These are Erythroxylon, Trichilia, Paullinia and Landolphia.

The genera Erythroxylon, Trichilia and Paullinia are all large genera which in existing floras, are mostly American but are sparingly represented in the African Tropics—Paullinia by a single species, if the identification can be relied upon. Paullinia also has a single species in the Sandwich Islands. One wonders whether this is a problem in plant geography or more likely a problem in systematic botany. There are two schools of plant geography—an older school which considers that the region where a group is most abundant is its original home, and a more modern school, probably best exemplified by the late W. D. Matthew, a vertebrate paleontologist, who held that the region of modern abundance is farthest removed from the original source. Neither view is correct to the exclusion of the other. Certainly the abundant and largely South American Sapindaceae, to which the genus Paullinia belongs, exemplify the older view.

The fourth genus, Landolphia, is relatively small and largely West African and is sparingly represented in South America, mostly in Brazil.

An extended analysis of the fossil flora and of the habits and habitat of those existing plants which are most similar to the fossil ones seems to indicate more genial conditions in Patagonia at the beginning of Miocene times than obtained in the earlier Tertiary. For example, no traces have been discovered of the numerous beeches so abundant in the Eogene flora. Not only was the climate warmer, it was also wetter. Among the genera of dicotyledons, about two thirds are commonly considered tropical and one third temperate. There is slight precision in the terms, and large genera are apt to occur under a variety of conditions.

There are several genera that survive in the temperate rain-forest region of southern Chile, such as Araucaria, Fitzroya, Laurelia, Libocedrus, Lomatia, Myrcia and Podocarpus, but in this Miocene flora there is no trace of the Fagaceae, which are now so prominent an element in that flora, as indeed they were in Eogene time.

Some of these genera may also be called Andean, in looking backward from the present, but the number is not large. They are exemplified by the spread northward at a later date, when the main Andean uplift occurred, of Polylepis, with its 15 Andean species reaching altitudes of 14,000 or 15,000 feet and extending to Colombia; by Styloceras, now found from Colombia to Bolivia and to altitudes of 12,000 feet; by *Lomatia obliqua*, which reaches Ecuador; and by *Podocarpus andina*, *Embothrium grandi-*

florum and *Schinus molle* which I have seen in the Peruvian Andes and which may extend much farther north.

Fourteen genera are considered to have been lianas. Nearly half of the genera have fleshy fruits, 19 being drupes and 20 baccate. Genera with capsular fruits number 20, and genera with winged or pappus-bearing fruits or seeds are also 20 in number.

To find assemblages like the fossil flora requires us to go northward from 10 to 15 degrees to the Argentine Mesopotamia, Paraguay and southern Brazil. Stated another way, it means that at the beginning of Miocene times, because of an amelioration of conditions many genera of equatorial America, which has remained the richest and largest area of tropical forest in the world, were enabled to spread southward over what is now Patagonia, some of the elements getting southward as far as Latitude 51° South. Of course the Andean backbone of South America could not have been in existence at the time because the fossil flora is identical on both sides of this axis.

If the Miocene conditions are compared with the existing conditions, there are the greatest contrasts. It would take a book to describe the present-day physiography and climate of the region. The lava plateaus and base-levelled steppes at levels from 2,000 to 6,500 feet, as well as the flat emerged old seabottoms at lower levels all appear as Pampas on the maps, seemingly euphumistic to those who have seen the pampas of Buenos Aires. At any rate to the south the precipitation varies to-day from about 8 inches to almost nothing, and whatever it is the evaporation is greater than precipitation and the whole country is treeless, wind-swept and inhospitable, with a short growing season, as may be realized far better by looking at the accompanying illustrations than by lengthy comment. It is quite erroneous, however, to think of this region as an Antarctic one.

North America extends so much farther from the equatorial zone than South America, and the climate of Patagonia is so inhospitable that the fact that Glasgow, Leningrad, Oslo and

Photo by Bailey Willis

VIEW SHOWING ABUNDANCE OF PETRIFIED TREES IN VALCHETA BASIN IN NORTHEASTERN PATAGONIA.

Stockholm are farther north of the Equator than Cape Horn is south of it is likely to be forgotten. The fossil locality on the Rio Pichileufu is almost in exactly the same south latitude as Bridgeport, Connecticut, is in north latitude.

In the accompanying text figure I have placed equal-area projections of North and South America side by side in reversed positions to show the correspondence in north and south latitudes.

Structural geologists have found out that the everlasting hills are not nearly as permanent as they seemed to the psalmist, for destroying forces beat against the high mountains like calumnies against human eminence, and if the geological time scale is taken into account both states are equally transitory.

Mountains are not permanent global features any more than coast lines—both are subject to ceaseless change. The most that may be said for mountainous regions is that they tend to be rejuvenated again and again after being repeatedly worn down, so that if we might borrow a phrase from medicine, we might say that orogeny tends to become chronic for certain regions. Thus, the Andes, one of the world's greatest mountain chains, experienced their most extensive elevation in times geologically modern, and long subsequent to the early Miocene that I have been describing. How old are these Miocene floras? I have yet to meet any one who has not laid his hand on the altar in the Temple of Paleontology who, shown a fossil, does not ask first of all, "How old is it?" even as Scrooge, confronted with the spirit of Christmas past, wanted to know "How long past?" According to the latest and current fashion of estimating the age of the earth by the seemingly precise methods of atomic disintegration, the flora I have been describing should have flourished about 25 million years ago. Perhaps what seems so certain may seem just as silly a generation or two hence as Lord Kelvin's classical estimates based on the rate of cooling bodies and before man knew about radio-activity.

I can never forget in this and similar situations an issue of the *Philistine,* the magazine published by that somewhat ribald philosopher, Elbert Hubbard, who at the time of the American visit of Sir Robart Ball—the astronomer royal—published what purported to be the coat of arms of Sir Robert and with the following superscription, "Hi olds knowledge by the tail, and stands ready to snap hof it goddam ead hoff."

SOME PHILOSOPHICAL REFLECTIONS OF A BIOLOGIST

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The Invasion of Philosophy

A certain consciousness of personal inadequacy in philosophic thought brings to mind an experience I once had in connection with a rabbit hunt on the Banks at Old Fort Macon near Beaufort, North Carolina. This isolated region, inhabited then by only one human family, that of the sergeant in charge of the fort, would each year become thickly populated with rabbits, which in autumn would be the object of a hunt, participated in by a considerable party who would descend upon the scene to combine raptorial, social and perhaps convivial activities in one grand thanksgiving half-holiday observance.

On one of these occasions, as I came out from the hotel in hunting togs, I was accosted by an old fisherman, who asked rather pointedly what I thought I was going to do. When told, he inquired in a tone of surprise and reproof if I did not know that the tide was on the ebb. I said yes, but what had that to do with hunting rabbits? "Don't you know," he said, "that you can't get rabbits when the tide is on the ebb, that they come out and feed only on the flood tide?" I said I had understood that some fish are addicted to feeding on the flood tide, but not terrestrial animals such as the rabbit. Feeding on the flood, my informer rejoined in a most positive tone, is universal among animals. It is, he maintained, a basic law of nature from which rabbits are no more exempt than pigfish or mullet. Then he added, sympathetically: "Ain't it strange that you have been to school and college, and I ain't never even been to school, and I know more about rabbits than you do?"

The immediate sequel to this incident was that we returned from the hunt with 35 rabbits! The application must be obvious. Isn't it strange that with those about us who have devoted years in college and university to the study of classical philosophy, a zoologist, who has never passed even the grammar grades in the subject, should presume to talk about philosophy? One may well anticipate with almost a feeling of awe the prospective bag of philosophic rabbits to which a disquisition such as this may be a prelude. The only sound defense, if there be any, for the present display of audacity is that there may be those who would be interested in one more answer to the question—how an everyday zoologist, if he gives any thought to the matter at all, attempts to orient himself in the field of synthetic thought.

It is, however, a fact that scientists of to-day, particularly those in the physical fields, are regularly looking across the international boundary line that formerly separated, if somewhat vaguely, the territory of science from that of philosophy. Indeed, this is far too conservative a statement. Some physical scientists not only cast their eyes across the line, but actually they step across in aggressive and solid ranks to demand, in the new territory, not merely spheres of influence but actual dominance over extensive areas of the fertile philosophic fields. Can it be improper, then, that there should be an occasional discussion of the philosophy of science from the standpoint of the oldest of the scientific

disciplines?[1] Need biology be immune against the modern "philosophization of science," in the words of Jasinowski?

Protoplasm and Thought

Applying ourselves now more directly to the stated topic, doubtless the first thought of a philosophic nature that must come to the mind of a biologist provided with an audience and the topic "Philosophy" is that he and his listeners constitute a gathering of masses of protoplasm, more or less shapely masses, each of which manifests itself with a high degree of specialization in different parts of each mass and with marked individuality in the wholes. The speaker has a protoplasmic base, and so has each listener. What the speaker thinks and what he says is an expression of the activities of some of the specialized bits of protoplasm that form a part of his total organization. As to the listeners, their interest or lack of interest, their acquiescence or criticism—all these are activities of specialized bits of protoplasm, activities that in a good physiological laboratory can be measured in terms of oxygen consumption. There seems to me to be no present escape from that conclusion, the implications of which may command our attention for a few moments.

It may be a stale quotation to the philosophers and to others, but an oft-quoted poem may serve a useful purpose in this connection:

> There was a young man who said God
> Must think it exceedingly odd
> That the sycamore tree
> Just ceases to be,
> When there's no one about in the quad.

[1] There may be those who would question a reference to Biology as the oldest of the sciences. The matter cannot be argued here, but there seems the best of reasons for believing that it was perhaps the first of the "disciplines" in which prehistoric knowledge was systematized and human welfare advanced through observation, experimentation, inference and generalization, with the generalizations sometimes quite incorrect, incomplete or even as doubtless are some of our current generalizations.

There was a reply to that which, unfortunately, I do not recall in its exact words, but it was in the nature of a poetical reply from the Almighty enjoining the young philosopher not to be concerned about what might happen to the sycamore tree under hypothetical conditions, because actually there was never a time when a Supreme Being was not "about in the quad."

This answer might conceivably give satisfaction to a theologian or a philosopher, but it gives none to a zoologist, and this without reference at all to his belief with respect to a Supreme Being. The zoologist feels entirely sure that the sycamore tree that he and his kind know can not be expected to exist for any being or person not provided with an eye with an eight-layered retina, an optic nerve and certain nerve cells in the brain, and all in good working order. As a matter of fact, the sycamore, as I know it, does not exist for one of my friends, who has certain deficiencies of the eye or of the brain: an important part of the tree, its bright golden autumn color, simply does not exist for him. When only this man is "about in the quad" the whole tree is not there. You could give any one of us a few drinks of a well-known fluid, and other essential qualities of the tree would be lost—the single trunk, the sharply defined twigs, etc. As a matter of fact, we do not ourselves, at best, see the tree completely—because our organs of vision are responsive only to the wave-lengths of light that fall within a limited range. Sever now the optic nerves and all the qualities of the tree, which we had been able to perceive through the eye, are lost, although others may persist. Assuming, as some one has suggested, fancifully but not altogether illogically, that the light waves could be slowed down, shortened and caused to impinge upon the ear, the sycamore would cease to be an image against the sky, but rather a clatter of sound or perhaps a piece of music. The thunderous crash of a tree in the forest

is, of course, non-existent without an auditory organ and its associated nerve tissue, and why not the color and the form of our tree without the vertebrate eye? Theoretically, with proper adjustments, the fall of the tree could be a flash of light rather than a crash. The reason we do not hear the lightning and see the thunder is possibly a mere matter of wave mechanics.

However it may be with sound, it should be well known to every one that we can translate pressure into light. One only has to press upon his eyeball to demonstrate the correctness of this statement. If we do not fool ourselves as to the actual existence of the stars or flares of light caused by pressure upon the eyeball, there is no more reason to fool ourselves as to the actual existence of the fall colors or the architectural characters of the tree *as we "see" them*. Something, yes, but not just those things.

This is not to say that without a vertebrate retina and cochlea there would be nothing in the place of the tree and the rustle of leaves. Indeed, if there were in the quad only a grasshopper with its compound visual organ, there would undoubtedly be something where we find a tree, but it would surely be something that we should not recognize as a sycamore tree. If now you or I should conceive of some other sort of eyes in the absence of any form of animal life, I have nothing to say about that except this: that the objects envisioned would not, *for any reason that we can see*, be what we know as a tree. Every bit of evidence that we have should convince us that there is not actually outside of the brain precisely such a thing *as the tree that is pictured on our brain cells*. Nor is there actually a brain cell such as we have seen in the laboratory except as the light waves coming from the preserved brain cell under observation with the microscope in the laboratory affect the retina of our eyes in such a way as to cause an alleged impulse to pass to the assumed cells in the cortex of the brain which in turn respond in such a way as to give us a picture that we know as the brain cell.

We are led to the broad generalization that all that we see and hear, all that we feel and think, all the knowledge and sensation we have are dependent upon the activity of the substance known as protoplasm as it is found in sense receptors, nerve fibers, brain cells, etc. Accepting this as a correct statement, and there seems to be no way to question it, we are led to the further and disconcerting conclusion that all we know about sense receptors, nerve fibers and brain cells or about protoplasm in any form is a result of the activity of protoplasm. We arrive at brain cells and protoplasm in just the same way that we arrive at the sycamore tree, and that is through the use of protoplasm. Protoplasm is itself, then, a protoplasmic product, in a subjective as well as in an objective sense.

Finiteness of Thought

Now, as I do not wish to seem to bog down in metaphysical subtleties, for which I am not personally adapted, I may epitomize what has been said in one brief statement, which is not a metaphysical but rather an eminently practical one; *viz.*, that all ideas are the fruits of protoplasm, and that protoplasm itself is an idea. Complete the syllogism, if you wish. What I would say now is that in our acquirement of knowledge and in all our intellectual activities we are obviously confined within a circle from which there is no escape. Whatever may be the condition of the physical universe, the universe of thought is certainly a finite one from the point of view of the biologist. It may be that the philosopher finds some way of stepping over the circumference of the circle that hems us in to soar out into a limitless space; but I can not resist the conviction

that he merely steps into the confines of another circle. If he can free the mind from protoplasm, which does not appear probable, can he free the mind from itself?

By way of parenthesis, let us note that there have been those who have conceived of the mind as something detachable from protoplasm. Certainly, however, all efforts to effect the detachment in any particular case have proven futile. Just recently a good North Carolinian living in another state undertook the age-old experiment of trying to retain his spiritual and mental faculties without meeting the demands of the protoplasmic base upon which they are thought to rest. It was no surprise to any one that his experiment failed after a long and painful period of trial. Should we laugh at a man who had the courage to submit his sincere, and to him well-bolstered, conviction to the crucial test? I do not think so; how much better it would have been, however, if he had known just a little biology! I do not know if it has occurred to others, apparently it did not occur to the experimenter in this case, that, with equal fidelity to his convictions, he could have made the experiment just as significant and conclusive within a period of five minutes and have saved himself and others the agony drawn out through weeks and months. While attempting to keep his body deprived of food, he overlooked entirely the fact that he was feeding it sixteen times every minute. If, besides shutting off the supplies of protein and carbohydrates, he had shut off the oxygen supply as well—that is to say, if he had tried to stop breathing—he could have learned within five minutes whether or not his higher faculties could survive without physical nourishment.

The conclusion we have reached up to this point may seem trite to the philosopher, but it has seemed worth while to show how the conception of a finite world of thought is inevitably arrived at by a consideration of the biological basis of man and of his thinking processes. "Seeing through a glass darkly" is a conservative statement.

There may be some who would say, but only thoughtlessly, I am sure, that the recognition of a limit to the possibilities of penetration into the mysteries of the nature of the world and man is an unhappy one. I see no basis whatever for discouragement or disillusionment in the idea of a finite intellectual world. How many of us are concerned or saddened by the fact that our physical bodies are unable to escape from the terrestrial sphere in which we live and where the longest possible journey in a direction straight ahead would eventually bring us back to the point from which we started? Even within a finite sphere there is ample room for all the perambulations we need or wish to undertake during the period of our physical existence. Physicists and mathematicians give no evidence of a loss of joy in life because of the conception of a finite universe with curved space. In fact, it seems to me that one of my mathematical friends derives a special kind of delight from the belief that a frictionless ball projected before him in a so-called straight line would eventually hit him in the back of the head.

There seems to be enough within a finite cosmos to occupy to the fullest degree the faculties of all the physicists and mathematicians that the earth is likely to produce within any period of time with which we need be concerned. Why, then, should any one be distressed by consideration of the fact that, by the very nature of the process of observing and thinking, we are confined within limits which are not likely to cramp us in our lifetime or even our descendants within a million years? The conditions we meet can be faced with unalloyed joy. No engineer weeps because he can not lift himself by his bootstraps, however

pleasurable an exercise that might conceivably be. Ordinarily, we do not like to go in circles, but there is no objection to a circular path if the circle be large enough. Such are the circles which we *always* follow afoot, or in automobile, train, steamship or airplane. And such are the paths in which our minds must travel, whether we be biologists, mathematicians or philosophers. It is a fact that every one knows, but regularly ignores, that if there were a perfectly "straight" road from New York to San Francisco, it would go far into the bowels of the earth; one would need no gasoline to coast the first half of the distance (drawing nearer to the center of the earth), but the latter half would be a long *up-hill* climb, although straight! It is only as a matter of convenience that we speak of straight lines in travel. Equally, it is only for convenience that we speak of reality in the world of thought.

In our further discussion, let us be guided by the principle of convenience, and let us treat of living beings and of objects just as if they were exactly what in practical life we conceive them to be. *It is the only way we can treat them!* I shall not think of you as figments of the chemical activities within the pyramidal cells of the cortex of my cerebrum, and you, I hope, will not look upon me and my phrasing of thought as a mere protoplasmic nightmare. We will assume ourselves and everything else to be just as real as they really are to us. For all practical purposes, we can forget the limitations previously mentioned, although they have a place somewhere in the background of our minds. Let us then look at protoplasm as a real substance and examine its character more concretely.

Some Qualities of Protoplasm

The first quality of protoplasm to command our special attention is its *instability*. There is nothing in the world as we know it more eternally unstable than protoplasm. While this is a well-known characteristic of the substance, I doubt if it always receives the conscious recognition it should have when we compare living with non-living chemical substance, when we assume, as we are naturally inclined to assume at times, that conceivably we will be able to take non-living substances and combine them in such a way as to produce living substance. The instability of protoplasm is not a mere example of the wearing away of a substance in which energy has been stored in the past; nor does it appear to be comparable to any ordinary reversible chemical reaction; nor even to an ordinary autocatalytic action (Gortner). It is an instability manifesting itself in so many directions that the condition at any future time has never been found to be entirely predictable from a knowledge of the past.

In respect to the origin of species or phylogeny we speak of "descent with modification." In respect to individual lives or ontogeny, we may well speak of *persistence with modification*. We will return to this thought again. Suffice it to say now that it is simply inherent in protoplasm to be reorganizing itself at all times. Stability in protoplasm spells death. If protoplasm is ever synthesized in the laboratory, the chemist must not only find the right groupings of materials in an extremely complex system, which he may well be expected to do; he must also get into that system, or find in it, this quality of eternal instability and something more which we will refer to in a little while. The Frankenstein conception had in it at least a germ of biological truth!

Possibly one can not always with certainty apply the qualities of the parts to the whole, but it seems reasonable to adopt, at least as a working hypothesis, the idea that instability will be a quality of any body made of protoplasm or of any combination of protoplasmic masses. As individuals we are combinations of

protoplasmic masses, and, therefore, both instability and unpredictability seem to become qualities of individuals. Social groups, academic groups, religious and political organizations, all these are combinations of protoplasmic masses and therefore by hypotheses, at least, are possessed of the fundamental quality of instability. We may assume that self-reorganization is an eternal quality of any social group. It is, then, not only in line with experience, but also a safe and reassuring philosophy of life to recognize that there is no logical possibility of attaining a stable economic, political or intellectual system. Stability may be death to them as it is to their protoplasmic basis.

The second fundamental quality of protoplasm, which appears to be in some respects a paradoxical corollary of the first, is its *approximate stability* (or constancy). Although living protoplasm is always in process of change, or at least possesses uninterruptedly the capacity for change, it nevertheless manages to remain essentially the same thing. It would not be protoplasm if it did not change, but, with all its continuous reorganization, it manages to maintain a relatively fixed organization or to proceed through a definite and roughly but not absolutely predictable series of conditions of organization. Any protoplasmic body might be regarded, as some one has said, as a vessel through which streams of matter and energy are flowing; but the matter and energy in passing participate in a definite organization determined in great part by the vessel.[1] The vessel seems to have an initial and characteristically changing organization; that prevailing at one moment determines the organization at another, and so on. The embryologist and the student of regeneration might have much to say here, but we can not go further now into a discussion that borders on the metaphysical or that might bring us before long against the impassable barrier that inevitably bounds our thought.

Parenthetically, there are probably some millions of different kinds of living organisms in existence in this day; each of these kinds is made up of millions of recognizably different individuals, and every individual, even among the Protozoa, is apparently made up of thousands or millions of different units of protoplasm; so that we arrive at astronomical figures if we attempt to enumerate the number of different protoplasmic units in activity at the present moment, all undergoing change, but remaining to a great extent unchanged. Gradual reorganization, without loss of characteristic *organization-control*, continues until, after a shorter or longer period of time, change, adaptive change, for some reason, becomes impossible, when the protoplasm becomes stable and, accordingly, ceases to be living protoplasm. This is the fate of cells, of individuals, of species, and seemingly of societies and of political and economic systems. Nevertheless, somewhere and somehow life goes on, and so do societies and politics, from seed that has been given off to shoot, flower and fruit, and to die after giving off other seed.

The biochemist who manufactures protoplasm must, therefore, introduce into his combination of materials both a condition of instability and a condition of stability enduringly characteristic of his particular protoplasmic product, but enduring indefinitely only through the power of reproduction from isolated parts—parts that become self-continuing and self-reproducing wholes.

The third quality of protoplasm to concern us now is its *inadequacy* as a basis of life. Nothing, indeed, could be more useless for the maintenance of life than protoplasm by itself. Its very instability demands interrelations with

[1] Furthermore, the streams of energy and materials flowing in have little relation immediately to the amounts flowing out, although in the long run there is no violation of the laws of thermodynamics.

outside or non-protoplasmic materials. In a sentence notable for its conciseness, Huxley reduced the protoplasmic doctrine to seven words: "Protoplasm is the physical basis of life." However exactly this statement fulfils the requirement of being truth and nothing but truth, it is certainly *not* the whole truth. Obviously, protoplasm is not the whole physical basis of life, since there is no manifestation of life without something in addition to protoplasm. Free oxygen or the equivalent is just as necessary to life as is protoplasm. All manifestations of life, as we now know them, are in the nature of responses to the addition of oxygen and other changes in the environment. Philosophers and biologists in general have recognized this truism and express it in such terms as "life is response."

It is the very responsiveness of protoplasm that must long, and conceivably forever, baffle the chemist in the analysis and reconstruction of protoplasmic behavior. I readily conceive of the complete analysis of protoplasmic substance and the *partial* reconstruction of protoplasmic behavior, but while keeping an open mind, I go no further now. If this seems to brand me as a vitalist, it is asked only that judgement be reserved for a short while.

Chemistry and Life

Life has a chemical basis and all the activities of living things, all the phenomena of life, may be the result of chemical reactions; at the very least they all appear to be accompanied by chemical reactions. It requires no argument to convince present-day biologists of these facts, although there may be differences of opinion in reference to the implications. We may cite just two or three sorts of facts which justify the broad statement just made. So far as we can tell from all observations, every manifestation of life, including mental and emotional as well as bodily action, results in the production of certain chemical products or wastes and in the demand for additional chemical substances, presumably for rehabilitation and reprovisioning of the tissues that were in action. If this were not evidence enough, we have the further condition that most of what we have learned about the structure of protoplasm and its changes during activity, physiological or embryological, is based upon detectable chemical change. What, for example, do we know about the mechanism of heredity, chromosomes, asters, chromomeres, etc.? Little more than what we have learned from the differential results of chemical reactions permitted to take place upon material representing a succession of stages of cell division, maturation of germ cells, fertilization, etc. A series of cells of different ages, when subjected to identical chemical treatment (fixatives, stains) gives us different end-products of chemical reactions; we see results that we identify as prophase, metaphase, etc. The chemical treatment applied was the same for all, but the end-products are subject to arrangement in a series parallel with the flow of time. We are bound to assume, I believe, that a series of unknown chemical reactions were occurring in the protoplasm and that it was, of course, the changing chemical constitution that conditioned the protoplasm to give the sequence of pictures that to us represent stages in mitosis, meiosis, etc. What we know, then, in regard to the series of activities is very largely what the chemical reactions have permitted us to see. Corroborative evidence from observation of living material convinces us that the chemical evidence is authentic.

Assuming, then, as we well may, that all the manifestations of life have a chemical basis, it might seem theoretically possible to hope for a time when the phenomena of protoplasm may submit to complete interpretation in chemical and physical terms, when a book of formulas, figures and expressions denoting atomic and molecular organization, nicely balanced reactions and diffusion and

osmotic rates might answer as a textbook of embryology or physiology. While no one would be so bold, at the present time, as to suggest the possibility of such a realization in the lifetime of any one now living, or in that of our immediate descendants, it may be suggestive to take a brief glimpse at the magnitude of the task.

In the first place, it should be understood that up to the present time not one single organic activity has been reduced to chemical terms. Let us assume that we have a tank with a million young free-swimming oysters, all at the stage when they should have settled down to the sedentary and steady life that well-behaved oysters are supposed to lead. In our experimental tank, however, they merely swim about in a scandalously irresponsible manner, getting nowhere and doing good neither to themselves nor any one else. Some one adds a trace of copper, as by dropping a penny into the tank, and the oysters promptly settle down, staking claims, as it were, to small areas on the bottom or sides of the aquarium where they will embark individually upon model careers of oyster life.[2] A normal behavior pattern has been interrupted for lack of the proper quality of a particular chemical element. Once this is supplied, the behavior pattern is completely restored.

But now let us suppose that the trace of copper had been added ten hours sooner, at two o'clock instead of at twelve. Would the oysters have settled? Not at all. In the course of the development of the oysters, between two and twelve o'clock changes had occurred. Predicate, if you will, that these changes were of a chemical nature, and reducible theoretically to a series of complex formulas leading up to a formula or combination of formulas, applicable at the moment the copper was introduced to effect a radical change in the mode of life.

[2] Alluding to work of H. F. Prytherch, *Ecological Monographs*, 4: 47–107. 1934.

Now if we assume that there were a thousand cells in the oyster at the stage of the beginning of our second experiment and that within each cell there were a thousand protoplasmic units in the form of genes, mitochondria, plasmosomes, protein molecules of nuclear and cell membranes and other components of the cell, we have a million or more possible chemical agents in each larva. It may be a theoretical assumption, but it seems a fairly reasonable one, that the greater proportion of this million or more biological units were performing some sort of essential activity at least once a second. Without involving ourselves too much in mathematical technique, we seem to have arrived by conservative procedure at a conclusion that some billions of chemical reactions must have taken place during the period of a few hours between the beginning of the observation and the time of settling. In short, to explain in chemical terms the activity that was precipitated by the introduction of copper into the tank, we need to lay the groundwork by following a billion or more preparatory actions. No doubt many of the chemical reactions concerned are duplications, but there is still every reason to believe that the diversity in the fundamental protoplasmic activities and chemical reactions is very great and great enough to justify the present argument in principle, at least.

The difference between the biochemical problem here and the ordinary problem in the chemical laboratory merits some thoughtful consideration: The time element, which figures, of course, in every chemical reaction, plays a so much greater and more significant and baffling part in the biological problem. This, of course, offers a whole field of thought and speculation into which we must not enter at the present time. Obviously the task of reducing the development of the larvae to chemical terms assumes the appearance of an exceedingly formidable one.

(To be concluded)

INBORN RESISTANCE TO INFECTIOUS DISEASE

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WHY are certain individuals spared during epidemics of infectious disease? The ancient notion stressed by Hippocrates was that some are endowed with a greater constitutional resistance than others, and to-day practising physicians still regard certain families and individuals as differing markedly in their ability to ward off prevalent infection.

The epidemiologist, however, has, for the most part, neglected this early theory and concentrated his attention upon the rôle of the inciting agent—the bacterium or the virus. His findings have come to form the basis of the current theory of epidemics, which is briefly summarized as follows (Text-Fig. 1). At the outset of an epidemic individuals in the population are supposed to have a uniformly low resistance. The epidemic is caused presumably by the sudden or gradual increase in virulence of an organism already present in the community or by the importation of an already highly virulent agent. The unfortunate individuals who succumb or contract a severe form of the disease are supposed to have encountered by chance large quantities of these virulent organisms. The epidemic is terminated according to this theory by a decrease in virulence of the causative agent and by an immunization of the remaining population constituents. This immunization presumably takes place in those who by chance have encountered only small doses of or less virulent organisms and hence have contracted a mild disease or hidden infection and thus developed a specific protecting mechanism. Such an epidemic theory ascribes the fate of the individual largely to chance.

This theory of the epidemiologist has now been subjected to an experimental study in the Rockefeller Institute according to new methods designated "experimental epidemiology." Populations of animals, usually mice, are assembled, some epidemic-producing organism is introduced, and the subsequent spread of infection studied under relatively natural and yet partly controlled conditions. Events are observed which closely parallel those occurring in human epidemics, hence an opportunity is afforded for the first time to study directly the question of what causes epidemics and especially why certain individuals are spared during epidemic times and others are not.

First, it developed that the virulence of the agent is not a fluctuating but a fixed property during the course of epidemics. Second, it was shown that population resistance could be altered experimentally and that such alterations incited or terminated epidemics in a predictable manner. Moreover, this knowledge renders the above current epidemic theory untenable and offers a more ready explanation on the basis of only one remaining assumption—differences in individual resistance (Text-Fig. 2).

The "experimentally developed" theory states that an epidemic is caused by an agent of high yet stable virulence introduced from without or by a general lowering of the average level of resistance to the agent already present in the community. This lowering of population resistance is followed by multiplication of the causative agent in already infected hosts and consequently an increase in amount or dosage of the agent

to which the community at large is exposed. This increase in dosage is the immediate cause of the epidemic whether the agent is introduced from without or already present within the population. Also in either case it is assumed that the individual constituents of a population differ widely in resistance, that those who first succumb or contract severe illness do so because at the outset they were most susceptible, and that those who escape entirely or with minor illnesses do so because at the outset they were more resistant. The epidemic curve is thus assumed to describe the differences in resistance of individuals and the average resistance level of the population to the disease-producing agent.

To test this assumption that individuals do actually (A) differ in inherent resistance and (B) succumb or escape an epidemic according to this initial resistance has been a matter of 15 years' study. To settle the first point required selective breeding experiments for some twelve generations; to demonstrate the second point epidemiological experiments were carried out for the first time with individual animals whose initial resistance was known and predictable.

(A). If an individual succumbing early in an epidemic is regarded as being inherently less resistant (rather than more unlucky) than the individuals who escape, it must follow according to genetics that its progeny must likewise be less resistant. By experiments on some 500 individuals it was found that those succumbing early in epidemics actually bear progeny more susceptible than those which escape. Thus our assumption became established that individuals differ profoundly in their inherent resistance to a given infection.

(B). To test whether certain epidemics are due to fluctuations in population resistance and whether those individuals who escape are those most resistant at the outset, populations must be made up

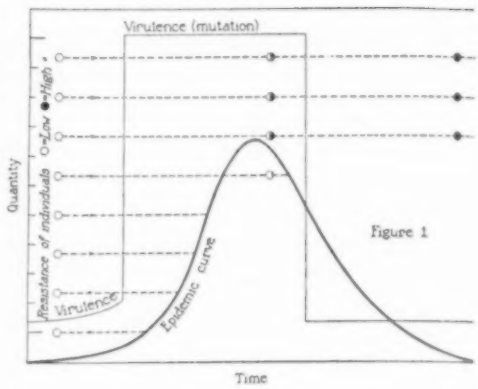


Figure 1

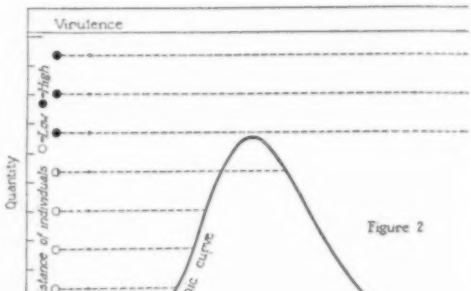


Figure 2

DIAGRAMS REPRESENTING MECHANISM OF EPIDEMICS ACCORDING TO CURRENT (FIG. 1) AND EXPERIMENTALLY DEVELOPED (FIG. 2) THEORIES.

of individuals whose resistance is known. This has not been possible until pure-bred lines of mice of known and uniform resistance were developed. From the progeny of resistants and susceptibles described above, however, (A), continued inbreeding and selection have been practised for fifteen generations until now lines of mice are at hand, generally indistinguishable except that one is 10,000 times more susceptible to a given infectious agent than the other. With different proportions of these resistants and susceptibles, various populations have been set up and a natural infection allowed to spread with the following results. If the population is comprised wholly of resistants, no disease or epidemic results. If the population consists entirely of

susceptibles, an explosive epidemic occurs fatal to nearly all. If the resistants and susceptibles are combined in different proportions and daily increments of each are added, the severity of the epidemic depends entirely upon the number of susceptibles and, with very few exceptions, the susceptibles alone are involved (Text-Fig. 3). The survivors of any given epidemic are almost entirely those individuals known at the outset to be inherently resistant. No acquisition of specific immunity on the part of the very occasional surviving susceptible has been observed.

Applying an experimentally developed theory of epidemics to human epidemiology involves certain difficulties. First, it is hazardous to reason by analogy from artificial experiments to field observations, where so many unknown and perhaps uncontrolled variables are involved. The experimental theory, however, rests upon data gained from a controlled study of six native animal infections observed under conditions as closely approximating nature as possible. Again, the facts of human epidemiology have been gleaned under circumstances in which many variables operate and relatively few are controlled—hence they are subject to a limited interpretation. The present discussion is confined, therefore, to those human infections whose nature and specific agent are fairly well recognized.

First of all, there are human infections whose prevalence fluctuates but little during a given year. These, of which tuberculosis is an example, are associated with causative agents whose virulence under natural conditions apparently remains stable. Their relatively high incidence in winter and their selective incidence appear to be due to differences in the seasonal resistances of populations and to individual differences in resistance.

The fluctuating or epidemic infections of man may be divided crudely into those which are blood-borne, food-borne or air-borne. Those which are blood-borne—yellow fever and malaria, for example—usually arise from infected human beings or animals whose blood has contaminated some insect vector following bite. This insect vector in turn pierces the skin of man and introduces the infectious agent into his blood stream. The prevalence of these infections fluctuates

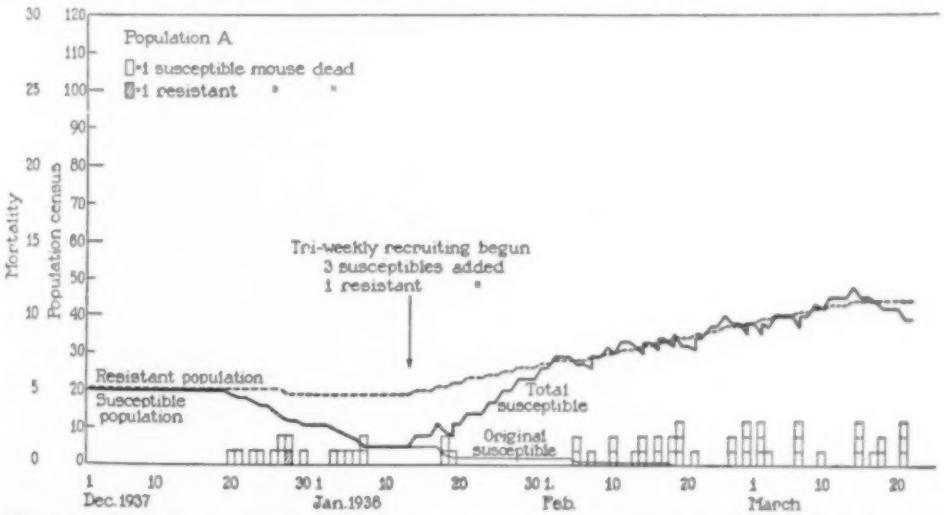


FIG. 3. SPREAD OF B. ENTERITIDIS MOUSE TYPHOID IN A POPULATION COMPRISED OF INNATELY SUSCEPTIBLE AND RESISTANT MICE.

markedly and epidemics occur of world-wide proportions. The infections occur chiefly in warm weather and curves of incidence parallel those of prevalence of the insect vector and of temperature and humidity. That is to say, warm weather determines the number of insects, and the number of insects determines the available dosage of the infectious agent and consequently the number of human cases. The selective incidence among individuals depends upon differences in their resistance following exposure.

The food-borne infections of man—typhoid and dysentery, for example—arise from the ingestion of food, water, milk, etc., to which the causative organism harbored by man has gained access and multiplied. These diseases are most prevalent and become epidemic in tropical climates and in warm weather. Under these circumstances the causative agent is best able to multiply in contaminated material. The increase in quantity of the agent or dosage available to the population is the immediate cause of the epidemic.

Finally, there is the group of air-borne infections—pneumococcus pneumonia, meningococcus meningitis, for example—which are transmitted directly from man to man by contaminated naso-pharyngeal secretions without the intervention of any further vector. They are most prevalent in cold climates and cold weather and there may assume epidemic proportions. Some condition acting directly upon man increases carrier rates and hence dosage of disease-producing organisms available to the general population. Most probably these unknown winter conditions reduce the resistance of the general population, since deaths from all causes are most numerous at this time. And differences in individual resistance again appear to determine the selective incidence of the infection.

Altogether the experimentally developed theory of epidemics fits the facts of human epidemiology better than the hypothesis of fluctuating virulence. Indeed, perhaps a crucial test has been the successful combating of the blood- and food-borne infections through a direct attack upon the dosage factor, that is, the control of insects and food and water contamination.

If the fate of an individual during epidemic times depends not upon blind chance but upon this initial resistance, efforts to analyze and increase that resistance are of fundamental importance to preventive medicine. Thus far it appears that the basic inherent resistance of an animal to a given infection is not so much manifest at the portal of entry or blood stream as in the specific tissues to which the agent has a special predilection. Thus, in St. Louis encephalitis infection of mice, the nasal portal of entry of resistants or susceptibles is equally receptive and the blood stream of both contains no antibodies. But once the virus reaches its tissue of choice, the brain in this case, it multiplies rapidly in and destroys the brain of the susceptible, while in the brain of the innately resistant it gains a transitory foothold and causes little or no damage. Finally, studies now under way indicate that the level of resistance which is inherited can be altered by many environmental factors, entirely aside from specific vaccines or sera. Not the least of these factors, for example, is diet. Toward a better controlling and enhancing of the resistance levels of populations and of individual man studies are now directed.

COMMENTS ON CURRENT SCIENCE

MISTLETOE IN LEGEND AND IN SCIENCE

PRESENT-DAY customs involving the use of mistletoe as a decorative plant during the Christmas season had their origin in ancient legends and beliefs which still prevail in Europe and America among simple folk. The strange appearance of the plant together with its comparative rareness in the northern part of its European range no doubt contributed to the belief in its great potency as a general panacea for all ills, including its power to cure barrenness in women and cattle. Anything so universally "good" naturally found a place in the customs centering about the joyous Christmas season. So began the custom of hanging mistletoe, with other evergreen plants, in prominent places as a decorative for the holiday season. Though many of the beliefs once accorded this plant have been largely forgotten, the youthful folk never forget that mistletoe is an excuse for uninvited(?) kissing.

The admittedly pagan origin amongst the Druids of the magical beliefs concerning mistletoe resulted in its being barred by the clergy from churches even for decorative purposes. This appears to have been true particularly in England during the past century. Its general use and acceptance by the people of all European countries and of America, however, has served to keep alive the customs of which the significances have been forgotten.

Fancied medicinal properties were numerous among the claims made for mistletoe. Decoctions taken internally or applied externally were believed to be effective, variously, in the cures of itch, epilepsy, convulsions, general debility, weakness of vision, cramp, wounds, sores, etc., *ad infinitum*, to draw "humours from the deepest parts of the body," and to serve as an antidote for poisons. No less prominent were the superstitions attached to the plant. It was credited with insuring success in hunting, and an amulet of its leaves served as a safeguard against all evil.

The more recently discovered facts concerning this odd plant are no less interesting than these beliefs which we now know to be untrue. The common name mistletoe is applied to many of the numerous species included in the family *Loranthaceae*, which is comprised of over twenty genera and several hundred species. More commonly known, however, are the genera *Viscum* in the Old World and *Phoradendron* in the New World. In Europe *Viscum album* L. is known as the common mistletoe and occurs throughout the Continent, except in the Far North, and in temperate Asia. Likewise well known is the red-berried mistletoe, or *Viscum cruciatum* Sieber, which occurs in Spain, northeastern Africa and Syria. It is from this species that legend ridiculously derives the wood which comprised the cross on which Christ was nailed; ridiculously, because the plant produces no wood sufficiently large and strong to serve as a staff, much less a structure to support a man.

When early explorers brought to Europe specimens of American mistletoe, these were described as species of *Viscum*, but subsequent students recognized the generic distinctness of the Old World and New World mistletoes and segregated the latter under the genus *Phoradendron*. No American species of *Viscum* are known and likewise no Old World species of *Phoradendron*. In America the most widely used mistletoe is *Phoradendron flavescens* (Pursh) Nutt. This plant occurs as far north as New Jersey, west to Southern Illinois and Texas, and south to Florida. On the West Coast it is represented by the related species *P. villosum* Nutt. Both these species have rather prominent green leaves and persistent white berries.

They so closely resemble *Viscum album* of Europe that it was with little difficulty and scant need for imagination that early European colonists in America accepted the American mistletoe as identical with the familiar European plant, and transferred to it the beliefs and customs which had been built up around the mistletoe of Europe.

Mistletoe is described as a semi-parasite. It grows in the form of a shrub on the branches of various species of trees. Its connection with its host is in the form of a *haustorium* or root-like structure which penetrates the host tissue and establishes a communication between the vascular tissues of the host plant and those of the parasite. Thus it secures water, minerals and elaborated food material from the host. At the same time the mistletoes (at least the commonly known species) have large green leaves and green stems by means of which they are capable of carrying on photosynthesis and elaborating their own food materials. That the parasite depletes the host's food material is evidenced by the stunting of infected host branches beyond the locus of infection. It has been demonstrated (unpublished) that a heavily infested tree kept divested of its own leaves can not subsist on the food elaborated by the parasite. This would indicate that there is little if any movement of food from parasite to host. Investigation has revealed that the cell sap of the parasite has a much higher concentration than that of the host tissue. This acts as a deterrent of the movement of water from parasite to host.

At best it is a bizarre plant upon which we have heaped the significances of legend, healing and custom.

CORNELIUS H. MULLER

COMMON USES OF PLANTS FOR CHRISTMAS DECORATION

COMING as it does in midwinter, the Christmas season has occasioned the use of those indigenous evergreen plants available to the people. Considering also the coincidence that some of these plants were thought to have remarkable curative and even magical powers, it is not surprising that some of them were early chosen as symbolical objects and have persisted as pagan elements in the celebration of Christmas. Add to this the esthetic appeal of green leaves in bare winter and persistent white and bright red or yellow berries, and one can readily understand why their use has continued to the present day.

Mistletoe with its green leaves and white berries is known to us as a symbol of Christmas, as has already been described. No less significant are holly and fir (Christmas trees). The *Tannenbaum* (*Abies pectinata* DC.) of early Nordic Christmas celebrations has been credited with having suggested, by its erect young cones, the use of candles on Christmas trees. Since the custom of setting up Christmas trees has spread with Christianity, the custom naturally has come to lands where fir trees are not to be found. There, any substitute suggestive of fir has been employed, and the other *Gymnosperms*, such as *Pinus*, *Pseudotsuga*, *Juniperus* and *Picea*, have been most sought after. Lacking these species, evergreen oaks have been pressed into service in our Southwest, or any evergreen tree or shrub which is readily available.

Holly (*Ilex aquifolium* L.) enjoyed a magical and therapeutic reputation second only to mistletoe in early European beliefs. For the same reasons it, too, has come to be associated with Christmas. The hollies number many species, but the spiny-leafed European holly with its red berries serves as the type for Christmas decoration. Of the several American species, *Ilex opaca* Ait. most closely resembles the European species. For the sake principally of their numerous red berries, *Ilex verticellata* (L.) Gray and *Ilex decidua* (DC.) Walt. are much used in America. Their leaves are smaller.

almost entire, and, in the latter species, deciduous.

Of less significance and of diminishing use on account of conservation programs are various species of clubmoss (*Lycopodium*). These serve principally as greens for the making of wreaths. Both European and American species are abundantly gathered for this purpose.

Local customs have occasionally arisen through the lack of the older, accepted plant materials for Christmas decoration. Thus, in the Southeastern United States the so-called Spanish moss (*Tillandsia usneoides* L.), a member of the pineapple family which grows pendant from the branches of trees, is used in large quantity for Christmas decoration. The somber gray hue of this dreary-appearing plant (though it is often dyed green for Christmas use) seems not to lessen the gaiety of the season's mood.

CORNELIUS H. MULLER

FIRE-RESISTANT CHRISTMAS TREES

A CHRISTMAS tree is a serious fire hazard. The risk is especially great where a large tree is used at a public gathering place such as a school or church. A living tree draws up water and dissolved mineral matter from the soil through its roots. If the stem or trunk of the tree is cut off above the ground and the cut end placed in water while the tree is still green, the stem retains much of the water-absorbing power of the roots, and the cut end takes up relatively large quantities of water. This water-absorbing power permits the introduction of dissolved substances into the tree after it has been cut. These circulate through the tree and are carried into the foliage.

Certain chemicals are able to render wood, pine needles and other flammable materials resistant to fire. Ammonium sulphate is about the best fire-resisting material. It is cheap and effective, and can be purchased from any seed store and from most hardware stores. Calcium chloride is also effective and cheap, but not so readily obtainable as ammonium sulphate. In addition to its fire-resisting properties, calcium chloride helps to hold moisture in the foliage and prevents the needles from dropping. If calcium chloride is substituted for ammonium sulphate, the same proportions should be used.

The method for making a Christmas tree less flammable is as follows: 1. Just before treating, cut off the end of the stem, preferably at an oblique angle or in a V shape, in order that the chemical solution may have free access to the fresh wood at the cut end. 2. Weigh the tree and divide the weight by four. This will give the weight of the ammonium sulphate needed. 3. Dissolve the ammonium sulphate in water, using one and a half pints of water for each pound of ammonium sulphate, and place the solution in a glass jar, tin pail or earthen crock. A narrow-mouth container is preferable because it lessens evaporation of the solution. 4. Set the tree in the solution in a cool place and leave it there until it absorbs the solution. For best results the treatment should be given at a moderate temperature—55 to 65 degrees Fahrenheit—before the tree is placed in a warm, dry room, because *the solution is not taken up satisfactorily when the atmosphere is warm and dry.*

It should be strongly emphasized that the degree of fire resistance depends upon the amount of the solution taken up by the tree. For best results *all* the solution should be absorbed before the tree is used. If the tree has been cut for too long a time it will *not absorb* the solution and consequently *can not be made fire resistant by this method.*

A word of caution should be added. A tree may be fire-resistant in the sense that it can not be ignited by a match of electric spark, and yet may catch fire from a large flame near it. It is customary to spread

a layer of cotton under the Christmas tree to imitate snow. If this cotton should catch fire, it might easily ignite even a treated tree, therefore, decorations on or about a tree should also be treated.

MARTIN LEATHERMAN

MORE MOONS OF JUPITER

DR. SETH B. NICHOLSON has just reported to the Carnegie Institution of Washington the details of his discovery of last July of two hitherto unknown moons of Jupiter, numbers X and XI.

Four moons of Jupiter were discovered by Galileo in 1610 with the first telescope ever turned toward the heavens. These moons are from 2,000 to 3,200 miles in diameter, and so bright under favorable conditions that they could be observed with the unaided eye if they were not lost in the bright light we receive from the planet. The satellites just discovered by Dr. Nicholson are only a few miles in diameter, possibly four or five, and they are only one two hundred thousandths as bright as the moons discovered by Galileo 300 years ago. They are so faint that it will not be possible to see them even through the giant 200-inch telescope which is now under construction in California. Dr. Nicholson found them by long-exposure photographs taken with the great 100-inch reflector on Mt. Wilson.

No satellites of Jupiter were discovered from 1610 until 1892 when Dr. E. E. Barnard found a fifth with the 36-inch telescope of the Lick Observatory. This is a small satellite about 100 miles in diameter and so close to Jupiter that its period of revolution is only twelve hours. Dr. C. D. Perrine discovered two additional satellites by photography, one in December, 1904, and the other in January, 1905. These are very small moons, probably between 20 and 80 miles in diameter, and revolve at distances from the planet of more than seven million miles. An eighth satellite was discovered by P. Mellotte in England in 1908, also by photography, and a ninth, by Dr. Nicholson in 1914. The eighth and ninth satellites revolve around Jupiter at distances of about fifteen million miles in periods of about two years.

There is much more to these discoveries of Dr. Nicholson than merely adding two new moons to a planet which was already known to have nine. Eight of the eleven moons of Jupiter, including one of those recently found, revolve around the planet in the direction in which it rotates on its axis and revolves around the sun. The other three satellites revolve in the opposite direction, all at about fifteen million miles from the planet and in orbits that are highly inclined to the plane of its equator. These retrograde satellites have a bearing upon the problem of the origin of the planets and the satellites, and they have posed problems that so far have not been answered. It is interesting that the facts and theories of modern science are so interrelated that our conclusions respecting the origin and early history of the planet on which we live depend on the properties of the motions of barren and lifeless little bodies which at their nearest are about four hundred million miles from us.

F. R. M.

SUPERGIANT "NEW" STARS

"NEW" stars, called Novae by astronomers, are stars which for some reason blaze out suddenly within a day or two, rising to a brilliancy exceeding the normal by perhaps a hundred thousandfold. And almost as mysteriously, these novae within a few days lose much of their luminosity, and decline within a few months almost to their original brightness.

Novae have played important rôles in the history of astronomy. It is believed that Hipparchus (about 160–105 B.C.) made his catalogue of 1,080 stars, the first star-catalogue ever constructed, because of the sudden appearance of a brilliant star where none had previously been seen. Possibly the Star of Bethle-

hem was an unusually bright nova. Certainly a never-dying interest in astronomy was aroused in Tycho Brahe by a "new" star which appeared in the constellation Cassiopeia in 1572, and which for a time was as brilliant as Venus. In 1604 a similar and nearly as bright nova appeared in Ophiuchus. In 1901 a very faint star in Perseus suddenly became as bright as any other star in the sky. In recent years, exceedingly distant, and consequently not very bright, novae have been frequently recorded by photography.

Astronomers have long been puzzled by the explosive increase in the rates of radiation of novae. There is no known method by which their energy can be transformed into radiation on such an enormous scale, for during their periods of great brilliancy novae are truly giants in light-giving power, exceeding by far all ordinary suns such as our own. Before astronomers had become accustomed to the amazing properties of these giants, they were astounded and bewildered by the discovery of supernovae, which exceed common novae in brilliancy as much as common novae exceed ordinary suns. These supernovae have not been observed within historical times in our own galaxy of billions of stars, but in distant galaxies so far away that light requires millions of years to come from them to us.

Dr. W. Baade of the Mt. Wilson Observatory has just reported in the *Astrophysical Journal* on the eighteen supernovae so far known. On the average, each of these eighteen astounding objects at its maximum brilliancy poured out radiant energy into space at a rate exceeding that of the sun a hundred million times. In some cases, at their maxima, they radiated more energy than all the other stars of the systems in which they appeared. If a supernova should appear in our own galaxy, it might easily give us more light than the full moon. Perhaps, then, astronomers would be able to determine definitely whether the mysterious cosmic rays have their origin in the supernovae, as has been suggested as one of the possibilities of their source. If our sun should become a supernova, or even a common nova, which is very improbable,—well, then the publication of the SCIENTIFIC MONTHLY would be permanently discontinued.

F. R. M.

REEFS OF SODIUM BICARBONATE

THE "rock candy mountains" of the hobo song are approached in actuality by discovery of thick reefs of baking soda buried in the earth, perhaps the first of this material ever found in nature. It has just been identified by Dr. William F. Foshag, Smithsonian Institution curator of mineralogy, from cores brought to the surface from depths of about 300 feet under an ancient California lake bed.

Used by housewives and dyspeptics for generations, sodium bicarbonate always has been a manufactured product, made from a base or ordinary table salt by a complex chemical process. A few years ago, came the first reported discovery of any of the natural mineral. It was identified, perhaps in error, by a British geologist in a chemical analysis of encrustations scraped from the wall of an ancient Roman aqueduct near Naples. It was declared a new mineral and given a name.

Some doubts have been thrown on this discovery by further tests, so that the material identified by Dr. Foshag may be rated as an original discovery. It was found under the dried bed of Searle's Lake, California, long known as a treasure chest for rare mineral combinations. There are approximately 150 feet of brine beds, deposited from the waters of an ancient salt lake. From these beds, by means of shallow wells, potash and borax are being recovered on a commercial scale. In the pumpings a complex of other minerals is found. Some time ago, Dr. Foshag suggested that drillings

be made below the brine layers. When the shafts were driven to the 300-foot level, it was found that layers of almost pure sodium bicarbonate and clay alternated. This time, Dr. Foshag says, there is no question whatever about the identification.

From samples obtained from the lower levels of the brine deposit, he has identified another new mineral, hitherto known only as an artificial chemical compound which has been named "burkeite."

THOMAS R. HENRY

A STRANGE FISH

ONE of the world's queerest and probably rarest fishes, a thread-like eel about seven inches long, has just turned up for the second time in history at the Smithsonian Institution.

A few years ago, Dr. A. W. Herre, of the Field Museum of Natural History, found the first specimen in a brook in New Guinea. The second specimen was obtained by Dr. Paul Bartsch, of the U. S. National Museum staff, in the open sea off the coast of Cuba. It apparently was attracted by a light lure from considerable depths. Both specimens, found thousands of miles apart and the only two of their kind ever seen, were superficially very much alike, so that they can be placed without hesitation in the same genus. The Cuban specimen differed sufficiently, however, to be described as a new species by Dr. Leonard P. Schultz, Smithsonian curator of fishes.

Both Dr. Herre and Dr. Schultz classify the new fishes as belonging to the general family of eels, whose principal characteristic is their thin, elongated body structure. The Cuban specimen has one peculiarity, however, for which it is unique among known fishes, although some varieties of blennies have something roughly approaching it. This is an organ consisting of two minute bone tubes opening just back of the head and burying themselves in the flesh of the head. Some blennies have hard spines in a similar position, but nothing which could be mistaken for tubes.

There is no clue whatsoever to the function of this unique organ, Dr. Schultz says. It might be revealed by dissection of the fish, but the single specimen in the world is far too important intact to be cut up for an anatomical study.

When caught, the little eel was gray in color and almost transparent. About the size of wrapping twine in the head region, it tapered off to the size of the finest thread at the tail. It is one of the smallest of the great eel family, Dr. Schultz says, but a few others are of about the same size. Superficially, it resembles the genus of "snipe eels" which are found at considerable sea-depths over most of the earth, but it lacks the extremely characteristic jaws of this genus.

At best, Dr. Schultz believes, the creature is rare. It may be more common than the two known specimens would indicate because it is just the sort of fish which would escape systematic collectors and be caught only by accident. For the great apparent gap in its distribution, there is at present no logical explanation.

THOMAS R. HENRY

THE "PERFECT" ANESTHETIC

GENERAL anesthetics have been used to produce pain-free oblivion during surgical operations for nearly 100 years, but the search for an ideal anesthetic still goes on in laboratories and operating rooms all over the world. Large numbers of chemicals have been tested for anesthetic properties, but, while some are better than others, none of them can be called perfect.

"A perfect general anesthetic," says Professor V. E. Henderson, of the University of Toronto, Can., Faculty of Medicine, "should produce not only absence of pain and loss of memory of the operation, but complete unconsciousness and such a deep depression of the central nervous system that painful

stimuli do not produce any muscular reflexes and have as little effect as possible upon the respiratory cardiac or other medullary reflex centers. It should further produce a state of very low tonus in muscles; complete relaxation of abdominal walls, as the surgeon puts it.

"It should produce its effect quickly without setting up undesired reflexes from the respiratory passages or elsewhere, and be free from direct stimulant effect on the basal ganglia when in low concentrations in the body. Its effects should pass off quickly and completely, leaving no indication of its action. Lastly, it should allow of the inhalation of adequate amounts of oxygen throughout its administration. No anesthetic has as yet fulfilled all these requirements."

Besides these effects on the body, the ideal anesthetic should have certain physical and chemical properties. It must have high solubility in lipoids as compared with its solubility in water. Lipoids are fatty substances found in the body. The ideal anesthetic must also have high chemical stability in the body.

JANE STAFFORD,
Science Service

THE CENTENARY OF CELL THEORY

BIOLOGISTS the world over have been observing, during the current year, one of the most important anniversaries in the whole history of science: the centenary of the cell theory.

It is difficult nowadays, when everybody, layman as well as biologist, takes cells for granted (even though he may never have squinted through a microscope), to realize that only three generations ago the idea of the importance of these little living bricks of which all living things are built was as new as the sunrise.

Yet so it is. To be sure, cells had been seen before. Early in the seventeenth century, as soon as the first crude microscopes became available, observers saw these objects, either as cavities in the tissues of larger organisms, or singly as "animalcules." But though seen, they were not rightly interpreted.

It was not until 1838 that the right eyes and the right minds were applied to the cellular problem. First came Matthias Jacob Schleiden, son of a Hamburg physician, who at the age of 34 brilliantly interpreted these minute subdivisions of the plants he studied as the ultimate organized living units. He described with considerable accuracy the course of cell division, and regarded it, correctly, as the essential basis of multiplication and growth.

General application of Schleiden's theory to both plants and animals was made by another German, the zoologist Theodor Schwann, much of whose career was spent in the Belgian universities of Louvain and Liége. He found nucleated cells in the tissues of some of his animals, especially in embryonic tissues, and established the general applicability of the cell theory to all growth and development.

Erik Nordenskiöld declares, in his "History of Biology": "It is thanks to this theory that the present age has been able to work out its conception of life-phenomena as a connected whole; without Schwann, Darwinism would hardly have been victorious."

FRANK THONE,
Science Service

THE RING STRUCTURE OF SILICA AND BORON

THE versatility of carbon is proverbial among all the elements found in nature. Carbon's ability to combine with itself in two ways—either in rings or in chains—accounts for its creation of hundreds of thousands of chemical compounds.

Arranged in chains, carbon makes possible petroleum, rubber, fats, the natural oils and the solvents. When the chains are turned around and form a ring, the chemicals typified by dyes, explosives, drugs and the synthetic resins result.

Chemists have long sought to make

other elements duplicate the unusual and extremely valuable type of bonding which carbon can achieve. The *Industrial Bulletin* of Arthur D. Little, Inc., reports that they are gaining their goal in this respect; at least in some cases.

The best success has come with elements, like silicon, which are closest to carbon in chemical characteristics. Silicon, like carbon, has the ability to join up with four hydrogen atoms in a molecule. And, like carbon also, it has the power to form compounds with itself known as silanes. These silanes are analogous to the carbon compounds, methane and ethane, found in natural gas.

Boron, too, is another element which can form compounds with its own atoms. Boranes may have as many as ten boron atoms linked in a chain. Both silanes and boranes ignite in air, sometimes with violent explosions.

By joining nitrogen and boron, chemists have succeeded in making a ring compound which is extraordinarily like benzene. In fact, the compound is called inorganic benzene.

It has practical significance in that, like real benzene, it is a liquid and a solvent for oils and fats. While it is not all that one desires even as a benzene analogue it may be a step on the way to improvements that will have important industrial applications. German chemists have been working in this field and it is comforting to note that American chemists, too, are studying the reactions.

ROBERT D. POTTER,
Science Service

RESEARCH IN THE STEEL INDUSTRY

STEEL once was considered the oldster among industries which did not know that constant research is the secret of perpetual rejuvenation. A decade or more ago there was a certain amount of scorn among practical steel men for too much flavor of research scientist.

Now that attitude has changed and the industry has changed with it. Just one of the big steel concerns has some 86 laboratories that conduct research primarily or incidentally, spending a cool $1,800,000 annually in scientific searchings. U. S. Steel Corporation began its major fundamental research program on a large scale in 1928.

Evidently it is good business for steel as it is for other fields. Dr. Rufus E. Zimmerman, vice-president in charge of research and technology for U. S. Steel Corporation, feels sorry for any steel expert who retired, say, 25 years ago, and who would try a come-back. He would be embarrassed by the mere size of open hearths and blast furnaces, feel out of place in continuous mills, hot and cold rolling a multitude of flat products, and need an interpreter for the new steel lingo of "slag-metal equilibrium," "measured deoxidation," or "controlled grain size." Alloy steels, including the stainless varieties, produced in electric furnaces would puzzle him.

Off production lines at the rate of so many miles per hour come steel products that would have been minor miracles a few years ago. Take the shiny steel sheet that goes into a huge press and comes out the two sides and top of an automobile. Those several square yards of metal must not crack under the strain of the terrific stretching and must be flawless on the surface.

A thousand automobile parts must be identical twins, one with another. Each must have the same desired grain size in order to harden the same way so as to act identically in the unrelenting rush of manufacturing and assembly.

Steel is even challenging the light metals, such as aluminum, in the airplane and streamlined train field. Stainless sheets as thin as 4/1000 inch and up to 190,000 pounds per square inch tensile strength are being produced that steel may do its share in speedy transportation.

WATSON DAVIS,
Director, Science Service

CULTIVATION OF THE MATERNAL INSTINCT

MOTHER instinct can be aroused by any one of six substances, one of them carbolic acid, according to a report just made to the trustees of the Carnegie Institution of Washington by Drs. Oscar Riddle and E. L. Lahr of the Carnegie staff.

They had previously reported that male rats and immature females could be made to "mother" infant animals when they were given injections of prolactin, the hormone secreted by the anterior lobe of the pituitary gland at the base of the brain which was first discovered by Dr. Riddle six years ago. One of the primary functions of prolactin is to stimulate the excretion of mother's milk, and it has been used with indifferent success to increase the milk production of cattle.

They now find that the mother love complex also can be aroused by injections of progesterone, one of the female sex hormones; testosterone, one of the male sex hormones; intermedin, a recently discovered pituitary gland hormone; extracts of the whole interior lobe of the pituitary gland; and carbolic acid. Meanwhile, other experimenters have reported that the same result can be brought about by removal of the thyroid gland in males and by the removal of the pituitary gland in immature females. The last report is especially puzzling to the Carnegie Institution workers because it involves a complete absence of prolactin in the blood stream.

The milk-producing hormone, Dr. Riddle's report shows, still is by far the most potent producer of mother love. It induced maternal behavior in more than three fourths of the female and more than half of the male rats. The female sex hormone was next, producing the syndrome in about two thirds of both males and females. The male hormone caused this reaction in more than half of the females but in only 15 per cent. of the males. The newly found pituitary hormone caused maternal behavior to appear in more than half of both sexes. Carbolic acid had the same result in 40 per cent. of the females and 24 per cent. of the males. There were no discernible effects after the injection of thyroid, parathyroid and adrenal gland hormones. Other sex hormones not only did not produce maternal behavior but seemed to inhibit it when it already was present.

The new results, Dr. Riddle points out, make more difficult than ever an explanation of the physiological mechanism of maternal affection, which first appeared on earth with the warm-blooded birds and mammals and which has been one of the most potent factors in evolution by making possible a prolonged infancy in which the young can be "educated" before they have to shift for themselves. The other substances, he says, may produce the effect by stimulating the pituitary gland to secrete more prolactin. Another possible explanation is that they act by inhibiting the action of other sex hormones, both male and female. Previous experiments have been reported in which the mother love of rats was completely destroyed by removing from their diet all the element magnesium.

Dr. Riddle reported to the Carnegie trustees some critical experiments with doves. He found that when crystals of the female sex hormone progesterone were implanted in the bodies of male doves, they started sitting on eggs. Then the crystals were removed, but the birds continued to sit until the young were hatched, and then proceeded to feed them until they were ready to fly away. This proves, he says, that the maternal instinct does not require the continuous action of the hormone itself. The progesterone seems to set off a complex interglandular reaction which, once gotten

under way, persists through the normal brooding cycle.

In another experiment, the rate of crop cell increase was determined from the onset of the "broodiness" in females. At the beginning this was found to be more than six times as great as at other times. The rate was increased still further during the whole incubating period until the first signs of crop milk appeared just before the eggs were hatched. This rapid crop growth is a basic action of prolactin. The experiment proves, Dr. Riddle believes, that the hormone is operating from the very beginning of the "mothering" period, although it may not necessarily be the cause of it.

Drs. Riddle and Lahr made nearly 2,000 tests with rats in their efforts to untangle the strange hormonal complex of mother love. It is essentially, they stress, a subconscious emotional reaction in which the brain apparently plays little part. They believe that its manifestations in human beings, where it is most prolonged, probably are due to the same basic physiological mechanisms as in the lower animals, but that in all human races it is affected by a great number of conventions which render objective study difficult.

Hormones, they point out, differ little from species to species. They now are trying to obtain purer and purer extracts of prolactin in an effort to clear their experiments of any effects exerted by small amounts of other pituitary hormones.

THOMAS R. HENRY

TISSUE CULTURE METHODS IN PLANT PHYSIOLOGY

SCIENCE has a way of closing in on a problem, once a breach has been made in the wall of difficulties surrounding it, that reminds one of an army capturing a city. Fronts of the various attacking columns maintain liaison and give mutual assistance as they move toward the common objective.

One such objective is the understanding of the physiology of plant cells and tissues. If we can get a better understanding of the way the cells act separately we can know more, and eventually do more in the applied field, about the way they act in the masses we know as organs and the organism as a whole.

But it is not easy to make plant cells or tissues act as isolated units. Not until about a decade ago did any one score an initial success. Then, Dr. William J. Robbins, of the New York Botanical Garden, was able to make roots survive for measurably long periods. But he could not induce them to grow.

Dr. Philip R. White, of the Rockefeller Institute, using a culture fluid containing several mineral salts, purified cane sugar and yeast extract, grew isolated roots indefinitely. He has scores of the little flasks containing growing roots that have not been attached to the parent plant for half a dozen years.

Yet these are fully organized roots—plant organs, rather than isolated tissues in the strict sense, and certainly not isolated cells. Success in culturing tissues and cells of plants is reported from two places in France. At the Sorbonne in Paris, R.-J. Gautheret has succeeded in producing masses of "just cells" from the cambium or growth-layer of certain trees, and at the University of Grenoble Professor N. Nobecourt and A. Dusseau have stimulated pieces of carrot into growing tumorlike masses of tissue.

The road is now open to start research on how isolated living units—"just cells"—behave when the immediate influence of the parent organism-as-a-whole has been withdrawn.

FRANK THONE,
Science Service

BOOKS ON SCIENCE FOR LAYMEN

SCIENCE FOR THE CITIZEN[1]

Upon reading the title of this large volume one wonders what was the aim of its author in writing it. Has he prepared a compendium of useful scientific knowledge that will enable the average citizen to operate the machines and gadgets he will encounter in his everyday life? The books of household remedies of a generation or two ago that prescribed a treatment for every ailment, real or imaginary, are precedents for such a volume. Or has the author shown that science is a form of ethics and religion, or that it contains all of philosophy? There are plenty of precedents for such an attempt.

"Science for the Citizen" is not an amateur engineer's handbook, nor a dissertation on philosophy or theology in the terminology of science. It is simply a book on science—physical science, engineering science, biological science, mental science. It is science in its historical development; it is the science of to-day, and it often looks toward science of the near future. It is astounding in the range it covers and in the enormous number of particularities it treats. In these respects the only comparable volume is H. G. Wells's "The Outline of History."

Science has become so varied and extensive that no man can become an expert in all of it. For nearly two generations it has become more and more specialized, both because of the impossibility of mastering all of it and also because of a too frequent false pride in ignorance of all except a very narrow field. These have been the days of exhaustive treatises on restricted subjects, which only specialists can understand. Now we have a book on all science in the grand style. It is quite likely that a specialist in each of the many fields it treats might complain that some of the statements are not exactly true without qualifications, or that they are not given proper relative emphasis. But we may inquire whether experience justifies confidence that the specialist always states only what is true, or whether he sets forth his own subject in proper relation to other fields. Judged by these standards he has generally proved that he could not be trusted.

Another method of surveying all science is for specialists in the various fields to produce a book in cooperation, as has several times been done. When the participating authors have gone so thoroughly over the contributions that each author has learned how imperfect his work has been for the purpose for which it was written, and has then corrected it, the results have been happy. Otherwise, they have not been very satisfactory. But there is much to be said for one man attempting to cover essentially the whole range of science, as Hogben has done. Outside of his own field he approaches the various subjects as his readers will approach them. He will write with the enthusiasm, and sometimes with the naiveté, of the discoverer. He will be eager to share his new knowledge with his friends. He will not be restrained by doubts nor feel under obligation to qualify endlessly his statements. He will be a crusader with plumes waving. All these things are illustrated abundantly in the work by Hogben.

It would be unfair not to insist that "Science for the Citizen" is a work of enormous content that can have been produced only by a prodigious amount of work. The author frankly and enthusiastically sets out to tell his readers

[1] By Lancelot Hogben. xxxii + 1082 pp., 480 illustrations. $5.00. American Edition. Alfred A. Knopf, New York.

what science is—not science softened and sugar-coated, but science that requires our best faculties for its comprehension. In the "Author's Confessions," which is or takes the place of a Preface, expressing the faith of the author in his public and being an indirect statement of his purpose, appears the following:

> In the Victorian age big men of science like Faraday, T. H. Huxley, and Tyndall did not think it beneath their dignity to write about simple truths with the conviction that they could *instruct* their audiences. There were giants in those days. The new fashion is to select from the periphery of mathematicized hypotheses some half-assimilated speculation as a preface to homilies and apologetics crude enough to induce a cold sweat in a really sophisticated theologian who knows his job. . . . The clue to the state of mind which produces these weak-kneed and clownish apologetics is contempt for the common man. The key to the eloquent literature which the pens of Faraday and Huxley produced is their firm faith in the educability of mankind.

After the recent sultry strivings for paradoxes and startling statements respecting creations, an exploding universe and scientific inferences respecting the characteristics of the Almighty, such words as those of Hogben are like a refreshing sea-breeze.

Hogben does not divide his material into mathematics, physics, zoology, etc., but he immerses it in the currents of human progress by grouping it in five conquests: The Conquest of Time Reckoning and Space Measurement, The Conquest of Substitutes, the Conquest of Power, The Conquest of Hunger and Disease and the Conquest of Behavior. No brief statement can give an adequate picture of the comprehensiveness, thoroughness and originality with which the author explains the progress of science under these five major headings. An attempt at any details where there is so much to be described would be misleading because of its inevitable inadequacy. If the author's faith in his fellow men is justified, his work is a success. And its success will be due in part to the very excellent illustrations of J. F. Horrabin, who also illustrated "Mathematics for the Millions," by the same author.

F. R. MOULTON

ANIMALS WITHOUT BACKBONE[2]

MANY universities have made noteworthy contributions both to knowledge itself and to methods for making this knowledge available, but few have undertaken as extensive a program in the latter field as has been done by the University of Chicago. Not only has a new program of study been instituted but new text-books have been written to meet the needs of the new courses. The most recent of these in the Biological Field, "Animals without Backbones," by Ralph Buchsbaum is especially interesting, for in many ways it departs widely from conventional texts. Its physical make-up is decidedly modern, and in places might even be called modernistic. A definite attempt has been made to have the book attractive so as to appeal to readers and make study easy and interesting. Its many illustrations are well done and the photographic material adds much to the value of the book. If a good illustration is worth a thousand words, as has been claimed, then this volume with its sixty odd pages of photographs in addition to the many drawings scattered through the three hundred and forty-two pages of text is actually the equivalent of a much larger volume.

The chapter headings are so worded that they catch the attention and whet one's curiosity. The various groups of invertebrate animals are clearly presented with a well-balanced distribution of materials so that no phylum has a disproportionate amount of space devoted

[2] An Introduction to the Invertebrates. By Ralph Buchsbaum. ix + 371 pp. Illustrated. University of Chicago Press. $3.50.

to it. This in itself is rather unusual, for it is so easy for an author to overstress any group in which he is especially interested. General principles are discussed in separate chapters, which is probably a good way to handle the material, but if they had been used to show developmental relationships they would have served to tie together much material which is otherwise unrelated.

The book is well arranged to meet the needs of courses in which Invertebrate Zoology is allocated about a semester's time whether these be listed as Invertebrate Zoology, survey courses or General Biology. It makes no pretense of being an advanced text, although it might well be used as an aid in such courses because of its fine collection of photographs.

At first glance it appears to be a very new type of text, but after reading it with great interest and considerable care I came to appreciate that it differs from the older texts much as modern college students differ from those of thirty years ago. A picture of a group of that period shows a very different-looking student, but after all the differences are in dress and customs. Fundamentally there is but little difference.

DONNELL B. YOUNG
THE GEORGE WASHINGTON UNIVERSITY

THE TROUBLED MIND[3]

THE author, according to his preface, purposes "to present a description of nervous and mental diseases in simple terms and to state some original theories concerning the nature of these disorders." In a series of 65 short chapters he gives a very considerable number of case histories to illustrate his comments on such subjects as compulsion neurosis, traumatic hysteria, epilepsy and the various types of the frank psychoses. Although the preface intimates that the book was written with the medical student in mind, it is, as a matter of fact, so oversimplified as to appear to be written down to the grammar school level. The case histories are extremely sketchy, and the explanation given by the patient as to the exciting cause is naively accepted without any suggestion that there might be any more fundamental cause for the symptoms. The author is apparently so wrapped up in his thesis of "to" reactions and "from" reactions that he omits entirely any reference to the extremely significant contributions of Freud to the understanding of the mechanisms of mental disorder. Even in the discussion of the frank psychoses there is an extremely lax use of terms, and at least one of his presumed cases of so-called paranoia is obviously a recurrent depression with feelings of suspicion rather than one of the classification to which it is attributed. It is astonishing that any modern-day psychiatrist would use such an antiquated word as "lunatic" or "lunacy," yet we find these words employed without any suggestion that they have no place in the psychiatric vocabulary. The book, on account of its oversimplification, its inaccuracies and its very serious omissions (there is hardly a suggestion in the book, for example, of the important rôle played by sex in mental disorders) can not be recommended either for the physician or the lay reader.

WINFRED OVERHOLSER, M.D.
SAINT ELIZABETH'S HOSPITAL,
WASHINGTON, D. C.

[3] A Study of Nervous and Mental Diseases. By C. S. Bluemel. Published by Williams and Wilkins Company, Baltimore, 1938. ix + 520 pp. Price, $3.50.

ADMINISTRATION BUILDING OF THE CARNEGIE INSTITUTION OF WASHINGTON AS IT APPEARS SINCE COMPLETION OF THE EXTENSION. ENTRANCE TO ELIHU ROOT HALL, THE NEW OFFICES AND THE EXHIBIT ROOMS IS AT LEFT CENTER. UNDER SUPERVISION OF THE ARCHITECT, MR. WILLIAM ADAMS DELANO, BUILDING OPERATIONS BEGAN IN SEPTEMBER, 1937. A COMMITTEE OF THE TRUSTEES, FREDERIC A. DELANO, ROBERT WOODS BLISS AND HENRY R. SHEPLEY, WITH J. MONROE HEWLETT, THE ARTIST, DEVOTED MUCH THOUGHT TO THE DECORATION OF THE HALL IN ORDER THAT, WHILE HONORING MR. ROOT, THE GREAT SCOPE OF THE INSTITUTION'S ACTIVITIES MIGHT BE APTLY SUGGESTED THROUGH ALLEGORICAL REPRESENTATION.

THE PROGRESS OF SCIENCE

ELIHU ROOT HALL OF THE CARNEGIE INSTITUTION OF WASHINGTON

DEDICATION of Elihu Root Hall marks the consummation of efforts initiated eight years ago by the trustees of Carnegie Institution to provide adequate facilities for conduct of the interpretational program of the institution that has been in course of development during the administratorship of President Merriam.

Entering the hall at the rear, the visitor's eye most quickly comes to rest upon the proscenium arch and above it the dedication: *To Elihu Root whose vision wisdom and devotion to the advancement of knowledge remain a source of inspiration.*

This inscription, framed by the intertwining branches of trees that rise on either side of the archway, is an expressive characterization of the interest taken in the affairs of the institution by Mr. Root, of whom President Merriam has said: "His influence will continue to be felt, and his voice to be heard, through the coming years, however far they may stretch."

On either side wall, at left and right of the stage, groups of heroic figures—astronomers, geographers, explorers—typifying the research workers of the institution, are represented as gazing in thoughtful contemplation upon the heavens, upon the waters beneath the heavens, and upon the lands bordering these waters—a range, indeed, that encompasses all the fundamental problems upon which modern investigators are at work.

The earth's curvature, as depicted on the side walls, is such that the rear wall of the Hall presents an expanse of sky that is unbroken except by the balcony. Against this expanse flocks of wild geese and of pelicans are shown in formation, winging their unerring course through the heavens—apt symbol of the certitude which the scientist seeks to achieve in his study of the universe.

Entirely encircling the room at base of these murals and binding them into a unit, are the incomparably majestic lines of the psalmist: *The heavens declare the glory of God; and the firmament showeth his handiwork. Day unto day uttereth speech, and night unto night showeth knowledge. There is no speech nor language where their voice is not heard.*

Another conspicuous feature of the auditorium is afforded by the transparencies set into the ceiling. These were made from actual photographs of the sun and moon taken at the Mount Wilson Observatory.

The transparency of the sun at the center is four feet in diameter. The photographs from which it was made were taken with the spectroheliograph, an instrument by means of which the sun can be photographed in the violet light of its glowing calcium, or in the red light of its glowing hydrogen, or in other spectral colors where the glow of gases in the sun is of sufficient intensity for the purpose. By shutting out all the rays from the sun except certain wave-lengths of calcium or certain wave-lengths of hydrogen, as the case may be, the respective photographs will reveal details in the sun's atmosphere which are lost in the tumult of mixed elements when photographs are taken in the usual way.

This transparency of the sun represents a combination of two photographs, one of the sun's disk, taken with the violet light of calcium and showing the sunspots particularly well; and one of the seeming edge of the sun taken with the red light of hydrogen and showing especially the so-called prominences of the sun, which are flames shooting up from it with incredible speed to distances

AN INTERIOR VIEW OF ELIHU ROOT HALL

of hundreds of thousands of miles, even to a million miles in one instance recently photographed and measured.

The transparencies of the moon are each twenty inches in diameter and show the moon in eight phases arranged in natural sequence and representing one complete lunation of twenty-nine and one half days. The photographs from which they were made were taken at the Newtonian focus of the great 100-inch telescope.

Although in every instance the transparencies are flat disks of glass they give the illusion of sphericity; this is merely because one is accustomed to thinking of the sun and moon as being spherical.

Completion of Elihu Root Hall and its system of engirdling offices, conference rooms and exhibition corridors focuses

attention upon the program which the institution has developed of explaining and interpreting the significant things derived from its investigations and of making such interpretations widely available, for it was the urge of this program, primarily, that led to erection of the new building.

THE AMERICAN ASSOCIATION MACHINE

PERHAPS the word "machine" is not quite appropriate in the title of these descriptive remarks about the work of the American Association for the Advancement of Science, for, in the first place, "machine" is a reminder of things political and, in the second place, I am really referring to the forces that make the association's machine function.

Since about two hundred scientific sessions will be held at the meeting of the association in Richmond in about four days, it is evident that from twenty to forty of them must be going on simultaneously most of the time. Back of every session there is an enormous amount of planning. Even the physical preparations are formidable, for adequate seating arrangements must be provided and assigned for all of them, and many of them require special equipment such as lantern slide projectors, motion picture projectors or microscopes. But, as I have indicated, I am not speaking of these things. Vergil said, "I sing of arms and a man"; I sing only of men.

The entire army of the association consists of about 20,000 members. It has 166 allies, technically known as affiliated and associated societies, the total mem-

THE ACCA TEMPLE MOSQUE, WHICH WILL HOUSE THE SCIENCE EXHIBITION AND MANY OF THE SECTIONAL MEETINGS

DR. J. R. KLINE

PROFESSOR OF MATHEMATICS, UNIVERSITY OF PENNSYLVANIA; CHAIRMAN FOR MATHEMATICS.

DR. HERBERT E. IVES

PHYSICIST, BELL TELEPHONE LABORATORIES; CHAIRMAN OF THE SECTION ON PHYSICS.

DR. HAROLD C. UREY

PROFESSOR OF CHEMISTRY, COLUMBIA UNIVERSITY; CHAIRMAN OF THE SECTION ON CHEMISTRY.

R. MELDRUM STEWART

DIRECTOR, DOMINION OBSERVATORY; CHAIRMAN OF THE SECTION ON ASTRONOMY.

DR. WALTER H. BUCHER

PROFESSOR OF GEOLOGY AND GEOGRAPHY, UNIVERSITY OF CINCINNATI; CHAIRMAN OF THE SECTION ON GEOLOGY AND GEOGRAPHY.

DR. FRANCIS B. SUMNER

PROFESSOR OF BIOLOGY, SCRIPPS INSTITUTION, UNIVERSITY OF CALIFORNIA; CHAIRMAN OF THE SECTION ON ZOOLOGICAL SCIENCES.

DR. RAYMOND J. POOL

PROFESSOR OF BOTANY, UNIVERSITY OF NEBRASKA; CHAIRMAN OF THE SECTION ON BOTANICAL SCIENCES.

DR. D. JENNESS

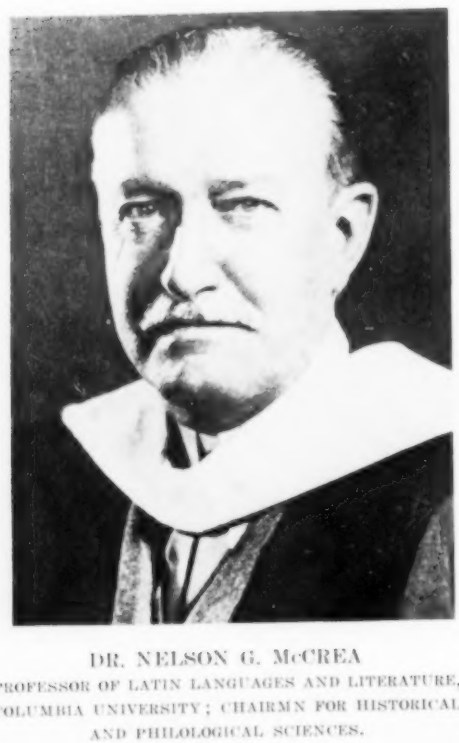
CHIEF OF THE DIVISION OF ANTHROPOLOGY, NATIONAL MUSEUM (CANADA); CHAIRMAN OF THE SECTION ON ANTHROPOLOGY.

DR. J. F. DASHIELL

PROFESSOR OF PSYCHOLOGY, UNIVERSITY OF NORTH CAROLINA; CHAIRMAN OF THE SECTION ON PSYCHOLOGY.

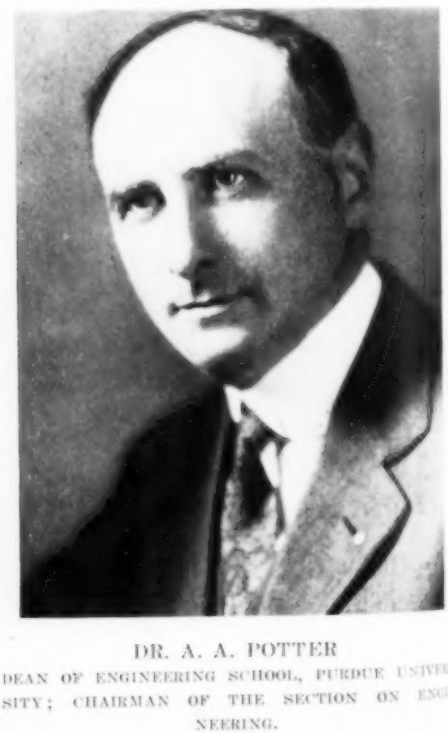
HOWARD ROSS TOLLEY

ADMINISTRATOR OF THE UNITED STATES DEPARTMENT OF AGRICULTURE; CHAIRMAN FOR SOCIAL AND ECONOMIC SCIENCES.



DR. NELSON G. McCREA

PROFESSOR OF LATIN LANGUAGES AND LITERATURE, COLUMBIA UNIVERSITY; CHAIRMN FOR HISTORICAL AND PHILOLOGICAL SCIENCES.



DR. A. A. POTTER

DEAN OF ENGINEERING SCHOOL, PURDUE UNIVERSITY; CHAIRMAN OF THE SECTION ON ENGINEERING.

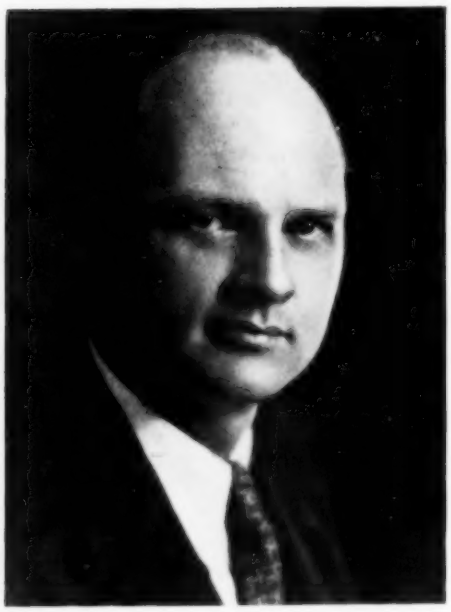
DR. T. M. RIVERS
MEMBER OF ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH; CHAIRMAN OF THE SECTION ON MEDICAL SCIENCES.

ROBERT M. SALTER
PROFESSOR OF AGRONOMY, OHIO STATE UNIVERSITY; CHAIRMAN OF THE SECTION ON AGRICULTURE.

society, depending on the number of its members who are also members of the bership of which (including duplicates) numbers several hundred thousand. There are probably altogether about 50,000 different persons in these organizations. The association itself has fifteen different armies or "sections," as they are called, which operate in the following fields: mathematics, physics, chemistry, astronomy, geology and geography, zoological sciences, botanical sciences, anthropology, psychology, social and economic sciences, historical and philological sciences, engineering, medical sciences, agriculture and education. Nothing appears to be overlooked except such arts as music, sculpture, painting, dancing and politics.

Each section, as well as each affiliated and associated society, has its own officers. These officers direct the active work of the association. The chairman of a section, who is also a vice-president of the association, holds office for one year and delivers an address, usually of distinction and wide general interest, at the close of his term. The term of the secretaries of the sections is four years. They do not deliver addresses nor appear in the limelight. They simply work, and if anything goes wrong or falls short of absolute perfection, they are almost certain to hear about it from either above or below, or from both directions. They are much like the Irishman who many years ago wrote to his friend back in the old country, "Pat, come over to this country as soon as you can. All you have to do is to carry the bricks and the mortar up the ladder and the men at the top do all the work."

The general legislative body of the association is the council, which consists of the officers of the sections, either one or two representatives of each affiliated



DR. GEORGE D. STODDARD

PROFESSOR OF PSYCHOLOGY, STATE UNIVERSITY OF IOWA; CHAIRMAN OF THE SECTION ON EDUCATION.

association, and a number of elected members. The council holds several sessions at each meeting of the association. At its last session in Richmond on Friday, December 30, it will elect a president of the association for 1939. The council elects an executive committee of eleven members with power to act in its place when it is not in session.

It is, however, the chairmen of the sections concerning whom I am writing, for in a sense they are at the head of their respective forces as they drive relentlessly into unexplored regions. In their respective fields they are men of distinction whose researches have made their names known throughout the world. They have received honors and medals, and one of them, Dr. Urey, has been a Nobel Prize winner. Their degrees and present positions are given beneath their respective portraits.

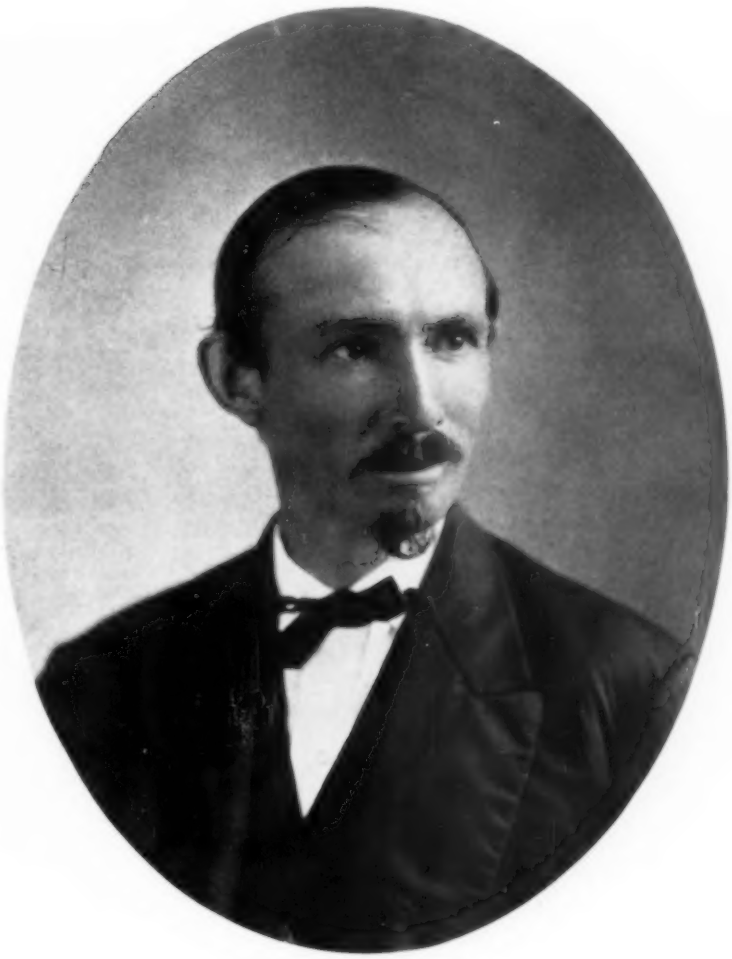
F. R. MOULTON
Permanent Secretary

GEORGE WILLIAM HILL AND JOSIAH WILLARD GIBBS

GREAT men, like lofty mountains, tower most conspicuously above their fellows when they are seen from a distance. In the case of men the distance may be in either space or time. For example, the intellectual eminence of both Hill and Gibbs was recognized from across the Atlantic before it was by those who saw them nearly every day. And from our distance in time we see, as their contemporaries never saw, that in the field of applied mathematics they were giants. On the basis of a few fundamental scientific principles, they outran observations and experiments and erected monumental scientific structures, somewhat as Euclid built geometry on a foundation of a few axioms.

Hill and Gibbs were born about one hundred years ago, the former on March 3, 1838, and the latter on February 11, 1839. During their lives their friends passed the time of day with them or made trite comments on the weather. Their successors now celebrate the hundredth anniversaries of their births. There is, of course, no special appropriateness in selecting the hundredth anniversary for commemorative ceremonies, for the two zeros in 100 are due to the fact that we use ten digits in writing our numbers; with twelve digits what is now 100 would be 84, which would mean eight twelves plus four. The only point of importance is that we are far enough from the lives and work of these great men to see them in excellent perspective. In the light of the progress of science during the fifty or sixty years since they were at the zenith of their powers, we can see how far they advanced beyond their contemporaries. Only recently has the scientific world overtaken them.

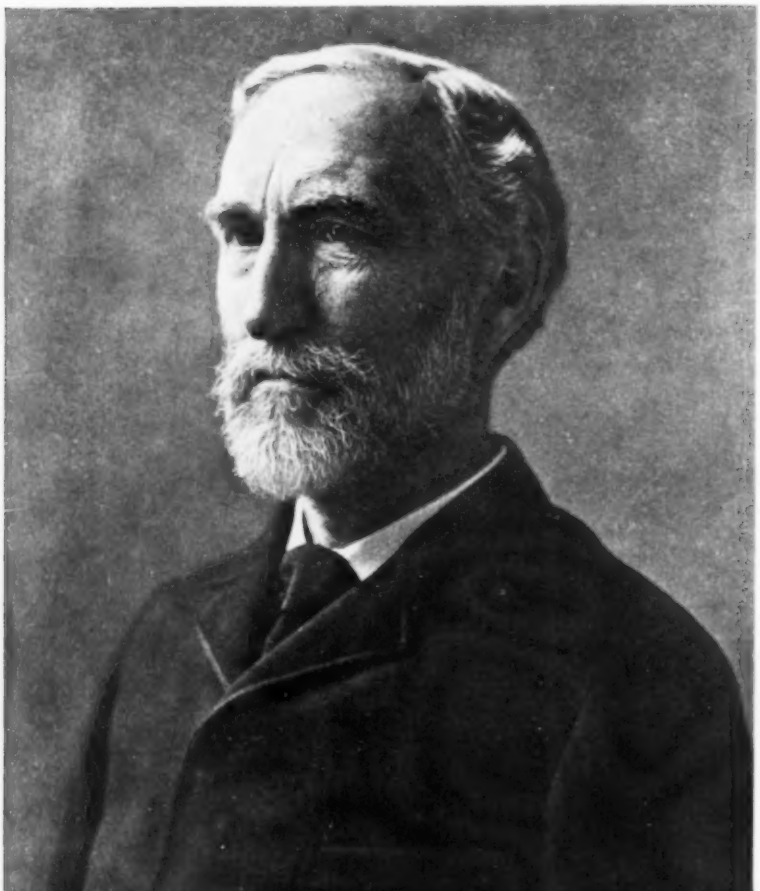
The greatest achievements of Hill were in the field of celestial mechanics; those of Gibbs were in the field of ther-



GEORGE WILLIAM HILL

modynamics and what may be roughly described as statistical mechanics. The fundamental principles underlying Hill's work were the laws of motion of physical bodies and the law of gravitation. His tools were the most profound mathematical processes, some of which he invented and developed. The products of his labors were theories of rare esthetic appeal which explained the motions of the heavenly bodies. Such achievements are enough to stir the emotions of the rare spirits who accomplish them, for they demonstrate that we can comprehend the laws of nature and deduce their consequences. And our results enable us to look forward in time, as our telescopes enable us to look outward in space.

The principles on which Gibbs based his theories were the law of the conservation of energy and the laws of thermodynamics. He considered mixtures of molecules in which the numbers of individual units were so great that they could not be individually followed. Yet by ingenious processes he determined their properties in the aggregate and thus proved that in apparent chaos there is essential orderliness. Perhaps some future genius will establish similarly that in the complex domains of our



J. Willard Gibbs

minds and emotions there is also complete orderliness. Experiments have verified the validity of Gibbs's processes and have raised them to the level of precious tools for investigation by those who can use such formidable means for penetrating the unknown.

The Royal Society of London, the Paris Academy of Science and the Belgian Academy felt it an honor to elect Hill to their memberships while he was yet almost unknown in his own country. The Royal Astronomical Society of London awarded him its Gold Medal, and the Petrograd Academy bestowed upon him its Schubert Prize. The Royal Society of London granted him the highest scientific honor in the British Empire, the Copley Medal, and the Paris Academy similarly honored him with its Damoiseau Prize. Columbia and Princeton Universities, Rutgers College and the University of Cambridge (England) granted him honorary degrees. He was

a member of the National Academy of Sciences.

Gibbs also received many honors, first in Europe and then in his own country. He was elected to membership in the Royal Institution of Great Britain, the Royal Society of London, the Bavarian Academy of Sciences, the Dutch Society of Sciences (Haarlem), the Royal Academy of Amsterdam, the Bavarian Academy of Sciences, the Cambridge Philosophical Society, the Royal Prussian Academy of Berlin, the Royal Society of Sciences (Göttingen) and the London Mathematical Society. He also received the Copley Medal from the Royal Society of London, and he was awarded the Rumford Medal by the American Academy of Arts and Sciences. The universities of Erlangen, Christiana and Princeton, as well as Williams College, bestowed upon him honorary degrees. He was a member of the National Academy of Sciences.

What of the families of Hill and Gibbs? Hill was of English and Huguenot descent. His father and his grandfather were artists, apparently in no way distinguished. When he was eight years of age his father moved from New York City to a farm at West Nyack, N. Y., where Hill spent nearly all his life.

Gibbs was of English ancestry and descended from a family distinguished for its scholars. On his father's side there was an unbroken line of six college graduates, five of whom were graduates of Harvard and one a graduate of Yale. Among his mother's ancestors there were two Yale graduates, one of whom, Jonathan Dickinson, was the first president of the College of New Jersey. Gibbs himself was a graduate of Yale and spent the remainder of his life, except for a period of study in France and Germany, as a professor in Yale.

Perhaps nothing in the lives of Hill and Gibbs is more interesting and instructive than their education. Hill graduated at Rutgers College and Gibbs at Yale, as many other boys before and since have done. It is probably safe to assume that they received as much inspiration and acquired as much knowledge from their courses as does the average student. But they both did something that was and is quite exceptional. They read the masters in science. While yet an undergraduate, Hill read carefully such great works as those of Lagrange, Poisson, Laplace, de Pontécoulant, Legendre and Euler, all of whom were French. Gibbs studied the works of Poisson, Cauchy, Fresnel and Clausius. Whether it was the qualities of their minds that drew Hill and Gibbs to the masters or the influence of the masters that inspired them to great achievements we can not know. But at least they understood the masters and took pleasure in following the paths they had trod.

F. R. M.

AN ANCIENT MEXICAN CIVILIZATION

A STADIUM with a seating capacity of at least 8,000, moat-encircled ruins of a town and a towered, twelve-room building are among the remains of an ancient civilization buried in the thick jungles of Campeche in southern Mexico, a land now traversed chiefly by wandering chicle hunters and found in a reconnaissance just reported by archeologists of the Carnegie Institution of Washington.

The party, led by Dr. Karl Ruppert, entered a region of dense forests, hitherto penetrable only with pack mules, by airplane and located the ruins of twelve towns which had flourished long before the discovery of America and, presumably, were built by close relatives of the Maya Indians.

For the most part, these were small places with few substantial buildings. The town in which the stadium stood was an outstanding exception. There was a

level area, about 60 by 70 yards, surrounded by a continuous mound, which was broken in four places for entrances. An examination of the enclosing wall showed that it had been lined on the inner side by a series of from 18 to 20 steps. These constituted the seats of the ancient stadium.

The place was probably used, the archeologists believe, for religious ceremonies and ball games. A game in which a solid rubber ball was bounced back and forth from the hips of the players with the object of getting it through a ring, as in present-day basketball, was very popular among the Mayas, and contests attracted large crowds. The game with many variations, extended northward as far as New Mexico and Arizona, and in central Mexico, had the patronage of the Montezumas. Even in the Mayan heyday, however, the Campeche region was probably bush-league territory. The ruins around the ancient stadium indicated the largest town in the region. The remains of several large buildings were made out, each with elaborate, stucco-decorated façades.

Not far from a little lake in the same general region, the explorers came upon the ruins of another town, now represented only by a few low mounds except for the remains of a single remarkable structure. This latter made up one side of the town plaza. It has twelve large rooms, and three towers—one at either end and one in the center. This last was more than 50 feet high. All the towers were semi-circular and had "false stairways" which were ornamented with great stucco masks. The building might have been roughly similar in appearance to a medieval castle. The moat-encircled town, adding still more to the medieval impression, was a few miles from the same lake in a different direction.

The number of ruins still discernible indicate that the region must have been at one time a flourishing population center. Difficulty of access has deterred previous explorers. The Carnegie party found, however, that several of the mounds had been opened by chicle hunters in search of buried treasure.

Dr. George Stromsvik, of the Carnegie archeological staff, reported the finding of another large ball-court in the ruins of the ancient Mayan city of Copan in Honduras. This was presumably a "big league" bowl where star athletes bumped rubber balls back and forth before cheering crowds more than a thousand years ago. Excavations show that it was the third similar stadium on the same site. It consisted of a long, rectangular playing area bounded on either side by a low, vertically faced bench from which sloping surfaces rose to a second vertical wall. On each wall were mounted three great stone parrot heads. All these heads had fallen down. It has been possible, however, to locate their original bases and they will be replaced. The floor of the playing-court was paved with flat stones. These have been distorted by pressure of tree roots, and it will be necessary to relay them.

Along one wall was found a band of hieroglyphic inscriptions from which it is hoped to find the approximate date when the stadium was built. One incised stone in this band was removed, and the archeologists found on its back another inscription showing that it had been taken from another ball-court on the same site. They found a date which they interpreted as indicating that the old court had been in use for 260 years before it grew too antiquated for the enthusiastic fans of ancient Copan.

THOMAS R. HENRY